The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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The Journal of Bone and Joint Surgery*

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TABLE OF CONTENTS

June 1958

PAGE

Scoliosis. [Editorial.]
By *Alan DeForest Smith, M.D.*, New York, N. Y. 505

Scoliosis—Quo Vadis? [Editorial.]
By *John R. Cobb, M.D.*, New York, N. Y. 507

The Milwaukee Brace in the Operative Treatment of Scoliosis.
By *Walter P. Blount, M.D.; Albert C. Schmidt, M.D.; E. Dudley Keever, M.D.;* and *Eugene T. Leonard, M.D.*, Milwaukee, Wisconsin 511

Making the Milwaukee Brace.
By *Walter P. Blount, M.D.; Albert C. Schmidt, M.D.;* and *Mr. Richard G. Bidwell (Certified Orthotist)*, Milwaukee, Wisconsin 526

A Critical Analysis of Methods of Fusion for Scoliosis. An Evaluation in Two Hundred and Sixty-Six Patients.
By *John H. Moe, M.D.*, Minneapolis, Minnesota 529

A Follow-up Study of the Treatment of Scoliosis.
By *Joseph C. Risser, M.D.*, and *Donald M. Norquist, M.D.*, Pasadena, California 555

The Pathogenesis and Treatment of Idiopathic Scoliosis. A Preliminary Report.
By *Adam Gruca, M.D.*, Warsaw, Poland 570

Compression in Arthrodesis. A Comparative Study of Methods of Fusion of the Knee in Ninety-Three Cases.
By *Marcus J. Stewart, M.D.*, and *W. Griffin Bland, M.D.*, Memphis, Tennessee 585

The Treatment of Certain Cervical-Spine Disorders by Anterior Removal of the Intervertebral Disc and Interbody Fusion.
By *George W. Smith, M.D.*, and *Robert A. Robinson, M.D.*, Baltimore, Maryland 607

The Management of the Burned Hand.
By *D. C. Robertson, M.D.*, Toronto, Ontario, Canada 625

(Continued on page 3)

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TABLE OF CONTENTS

(Continued from page 1)

PAGE

The Surgical Reconstruction of the Upper Extremity Paralyzed by Poliomyelitis.
By *Edwin R. Schottstaedt, M.D.; Loren J. Larsen, M.D.;* and *Frederic C. Bost, M.D.*, San Francisco, California ... 633

Osteochondritis of the Greater Trochanteric Epiphysis.
By *Thomas D. Hall, M.D.*, Chicago, Illinois ... 644

Ossification of the Distal Femoral Epiphysis.
By *John Caffey, M.D.; Samuel H. Madell, M.D.; Charles Royer, M.D.;* and *Pablo Morales, M.D.*, New York, N. Y. ... 647

Age of Fitting Upper-Extremity Prostheses in Children. A Clinical Study.
By *James A. MacDonell, M.D.*, Grand Rapids, Michigan ... 655

Arthrochalasis Multiplex Congenita. Congenital Flaccidity of the Joints.
By *Julius Hass, M.D.*, and *Robert Hass, M.D.*, New York, N. Y. ... 663

Primary Vitallium-Mold Arthroplasty for Posterior Dislocation of the Hip with Fracture of the Femoral Head.
By *Patrick J. Kelly, M.D.*, and *Paul R. Lipscomb, M.D.*, Rochester, Minnesota ... 675

Cervical-Spine Injuries in Children.
By *James P. Dunlap, M.D.; Martin Morris, M.D.;* and *Robert G. Thompson, M.D.*, Chicago, Illinois ... 681

Electron Microscopy of the Primary Spongiosa of the Metaphysis at the Distal End of the Femur in the Newborn Infant.
By *Robert A. Robinson, M.D.*, and *D. A. Cameron, M.D.S.*, Baltimore, Maryland ... 687

Recent Observations on Bone Structure.
By *Bengt Engfeldt, M.D.*, Uppsala, Sweden ... 698

Quo Vadis Orthopaedia Americana. [Editorial.]
By *Frederic C. Bost, M.D.*, San Francisco, California ... 707

Elven J. Berkheiser, M.D. ... 713

Proceedings:
The American Academy of Orthopaedic Surgeons.
Scientific Sessions ... 715
Scientific Exhibits ... 732

Addresses of Contributors ... 742

List of Advertisers ... Adv. 64

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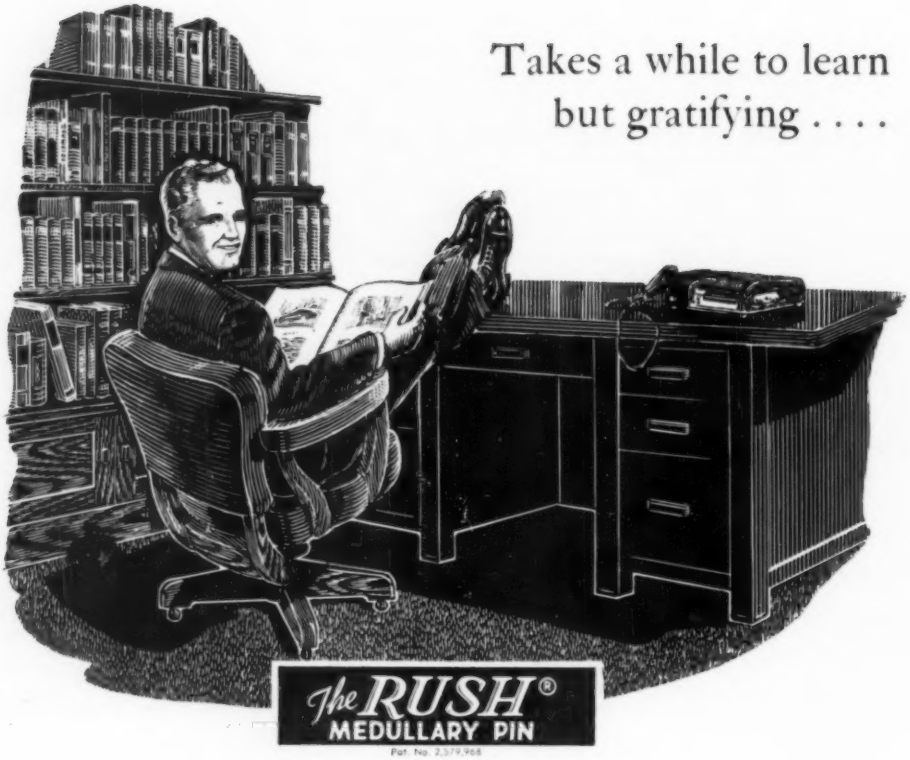

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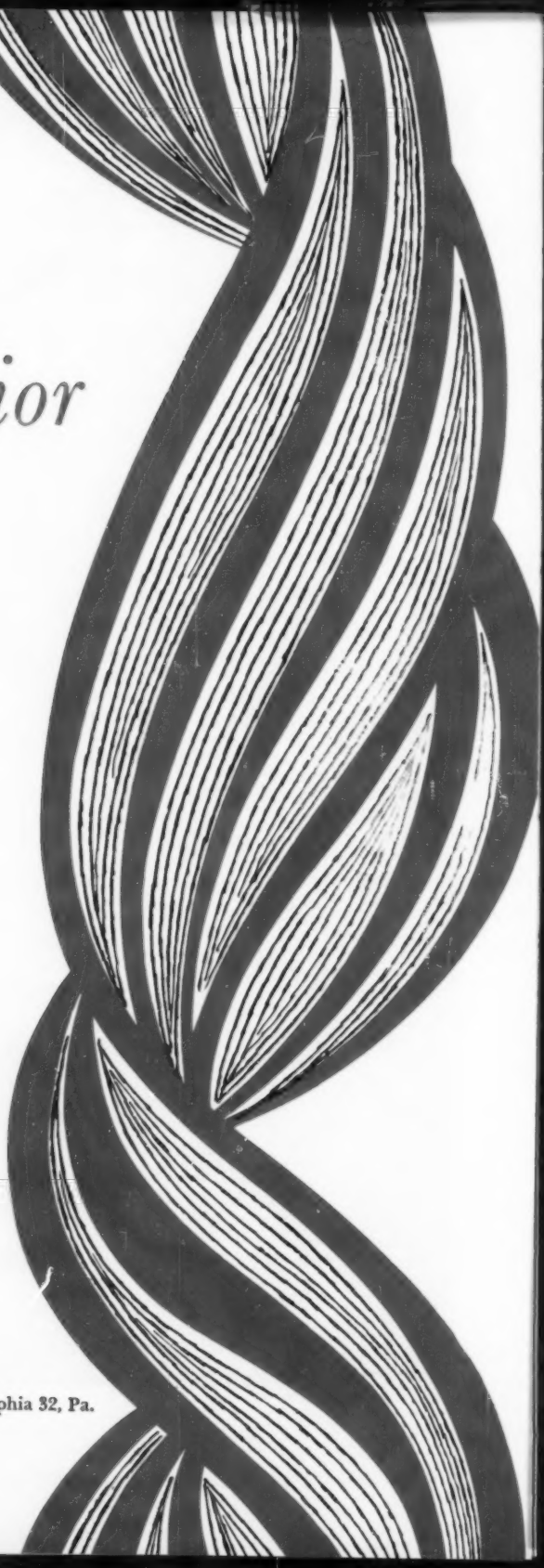

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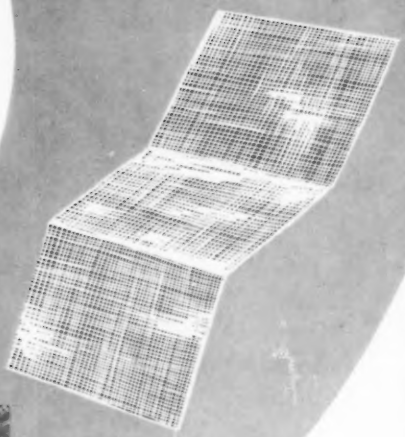

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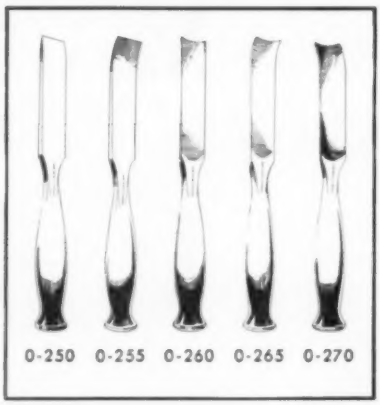

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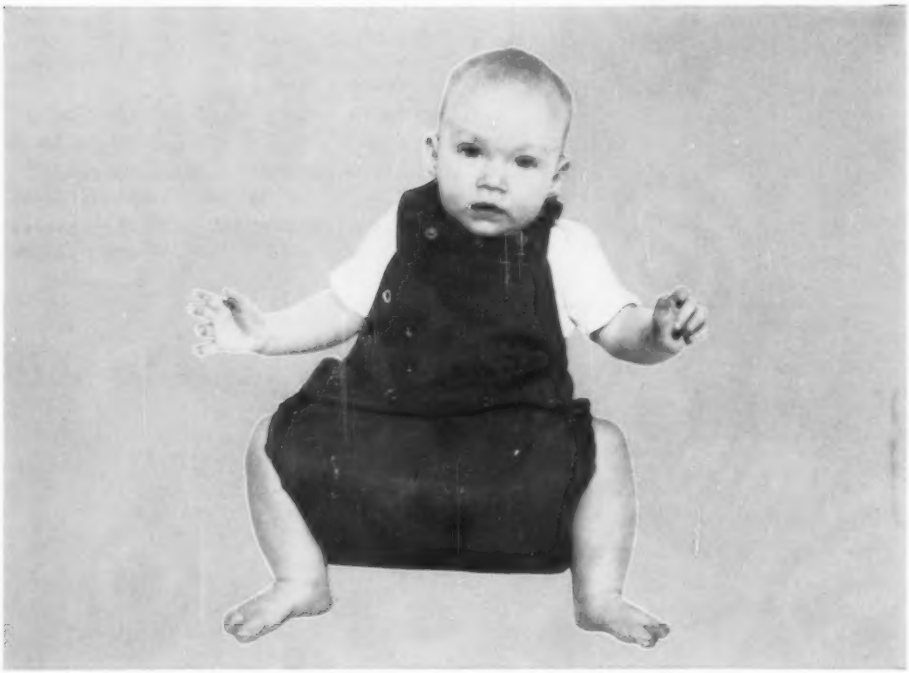

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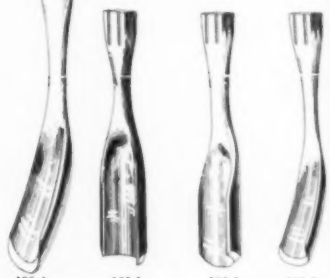

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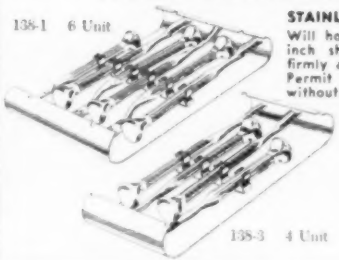

138-1 6 Unit

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STAINLESS STEEL

Will hold any instrument with a ⅜-inch shank. Will hold instruments firmly and prevent possible damage. Permit sterilization of instruments without individual handling.

FEATURES:

"Four and six unit trays will nest, one on top of the other." "Trays may be placed on end." "Requires less storage space." "Instruments cannot fall out if tray is turned over."

105-5

HATT SPOON—SPINAL GOUGE

In spinal and arthroplasty surgery, the use of the Spinal Gouge along with our Arthroplasty and Goose Neck Gouges give the surgeon a combination of instruments best suited in this often difficult and intricate work.

FEATURES: "Keen cutting edge." "Hardened and tempered to rigid specifications for maximum quality." "Thumb rest handle designed to insure grip and prevent slipping." "Long handles for unobstructed vision."

No. 103-5 Hatt Spoon—Spinal Gouge.

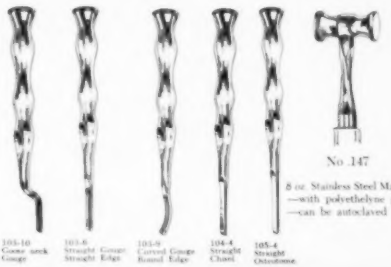
NOTE: Available with finger grips if desired.

CHISELS—GOUGES—OSTEOTOMES

For Surgery of the Hand

Type 440C Stainless Steel—Swedish Hand Forged

Contoured handles to comfortably fit the fingers of the hand so that holding the instruments will be easy and with a secure feeling. The average overall length of the instruments is approximately 6½ inches. The chisels and osteotomes are available in a goose neck blade such as illustrated below by the goose neck gouge.



103-10 Goose neck Gouge

103-6 Straight Gouge; Straight Edge

103-9 Curved Gouge Round Edge

104-4 Straight Chisel

105-4 Straight Osteotome

No. 147

8 oz. Stainless Steel Mallet —with polyethelyne grip —can be autoclaved

Compazine*
prevents postoperative nausea and vomiting
'Compazine' can be depended upon to have little, if any, hypotensive effect.
Available: Ampuls, Multiple dose vials, Tablets, Spansule† capsules, Syrup and Suppositories.
Smith Kline & French Laboratories, Philadelphia
*T.M. Reg. U.S. Pat. Off. for prochlorperazine, S.K.F.
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ORTHOPAEDIC *and* FRACTURE TABLE

● Acknowledged as the most versatile in its field, the American-Albee Orthopaedic and Fracture Table enables the orthopaedic surgeon to achieve "perfect positioning" of short, tall, obese and even infant patients . . . easily and rapidly. It is designed to accommodate closed fracture reductions as well as the increasing demands of complex orthopaedic surgery. Thus, to orthopaedists the world over, the name American-Albee identifies the table of choice for this comprehensive branch of medicine.

Ideal complement to this improved table is the American DV-22 Major Surgical Light . . . a new concept in easily maneuverable illumination . . . cool, shadowless, color-corrected . . . intensity to 10,000 foot candles *from a dual source.*

● *Write for Fracture Table Brochure TC-100R and Major Light Catalog LC-121R.*

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effective FIXATION

Anatomically correct . . . therapeutically sound . . . these principles are designed in, and built in, each Truform appliance.

Effective support or effective fixation . . . this you can depend on when you prescribe "Truform." Your patient benefits from the most careful selection and skillful fitting because . . .

- **TRUFORM Anatomical Supports are available only from the Ethical Appliance Dealer**

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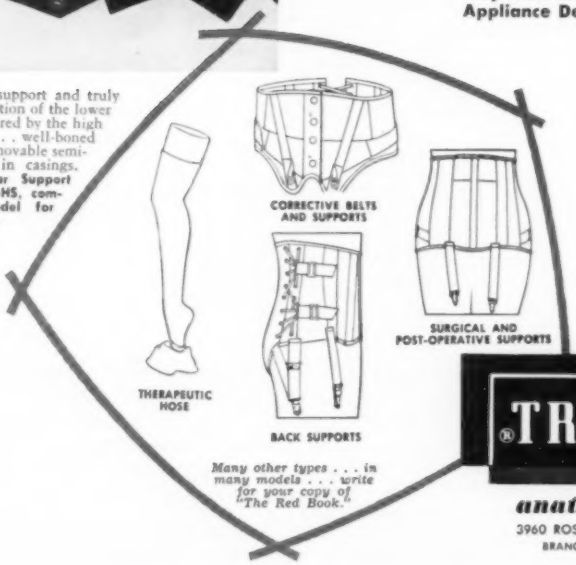

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PEPTIC ULCER.....less than 1½%

OSTEOPOROSIS.....only ⅙ of 1%

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never reported with METICORTEN– noted with the more recent steroids — unexplained leg cramps, lightheadedness, headaches, tiredness, weakness, anorexia

1, 2.5 and 5 mg. white tablets

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nothing takes the place of experience especially in long-term steroid therapy

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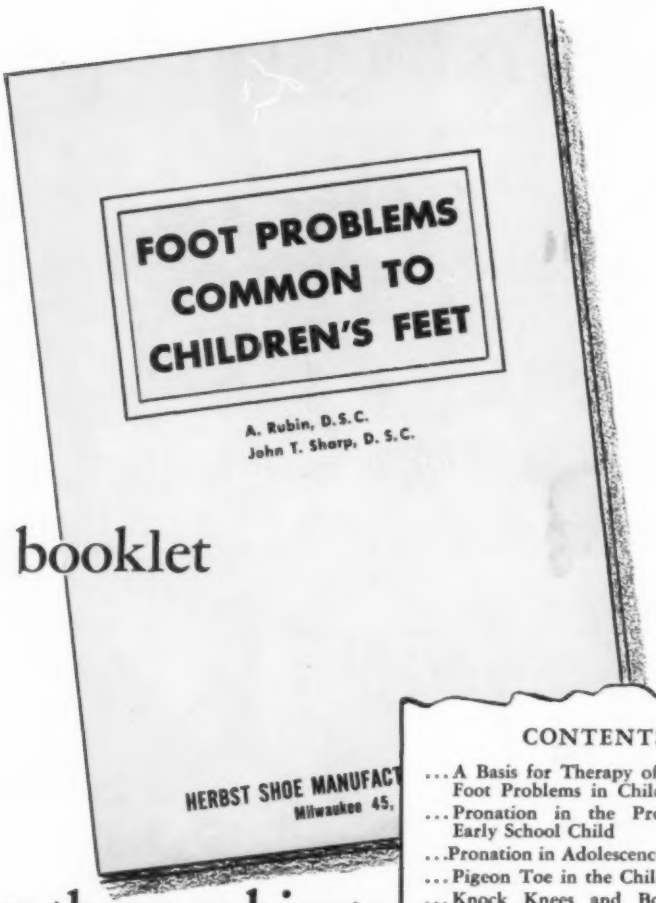

This booklet

covers these subjects

CONTENTS

- ...A Basis for Therapy of Mechanical Foot Problems in Children
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- ...Pronation in Adolescence
- ...Pigeon Toe in the Child
- ...Knock Knees and Bow Legs in the Child
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and it's yours for the asking

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HERBST Shoe Manufacturing Company, Milwaukee 45, Wisconsin

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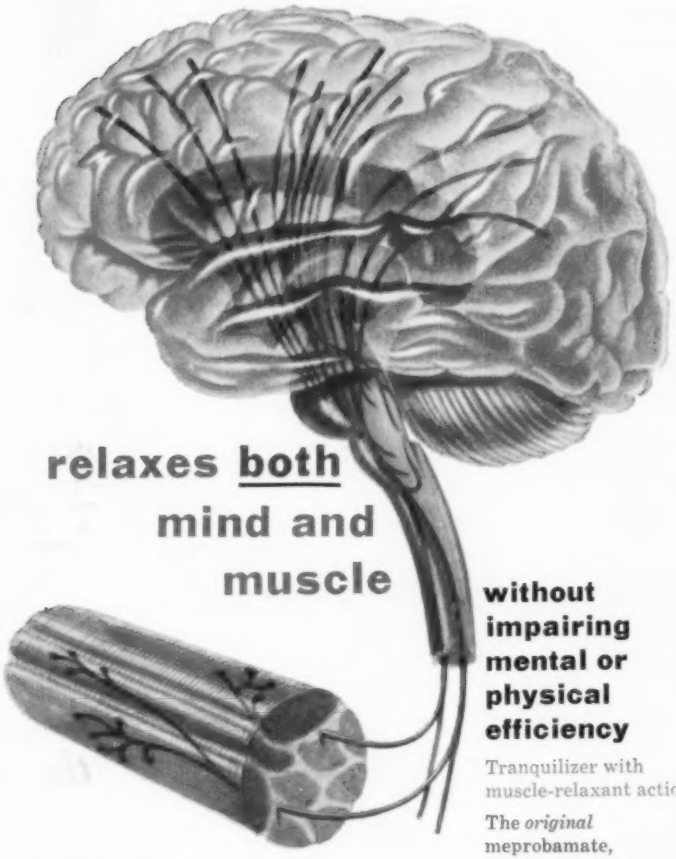

relaxes **both** mind and muscle

without impairing mental or physical efficiency

Tranquilizer with muscle-relaxant action

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Hanger Limbs are being successfully worn by amputees of all ages. David Canfield, just 13 months (illustrated), is one of the many young children growing up on Hanger Legs. In contrast, Captain W. T. Taylor, over 75 (illustrated), now wears his fifth Hanger. He is a fire inspector who must cover continually hospitals, schools, sports events, etc., and be on his feet for hours at a time.

The success of Hanger Limbs with amputees of such widely varying types can be largely attributed to custom manufacture and individual fitting. Unusual conditions are carefully investigated by experienced fitters, and limbs are manufactured to meet individual requirements. The experience of Hanger's 90 years is given to every amputee so that his rehabilitation may be successful.

AGE: 13 MONTHS

AGE: 78 YEARS

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Washington 13, D. C.
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Midwestern Region:
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Cincinnati 29, Ohio
Dallas 1, Texas
Evansville, Ind.
Fort Wayne, Ind.
Indianapolis 2, Ind.
Oklahoma City 3, Okla.
Peoria 4, Ill.
St. Louis 3, Mo.
Wichita, Kansas

Central Region:
Columbus 8, Ohio
Pittsburgh 1, Pa.

Southeastern Region:
Atlanta 1, Ga.
Birmingham 1, Ala.
Columbia 5, S. C.
Jacksonville, Fla.
Knoxville, Tenn.
Miami 37, Fla.
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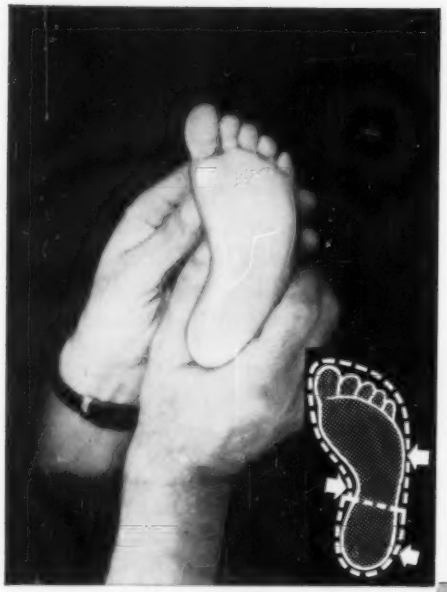
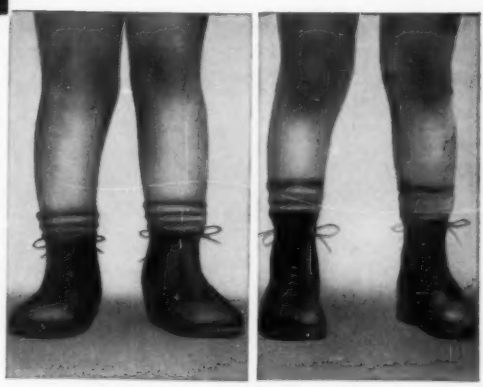
the action of the TARSO SUPINATOR SHOE



. . . swings the hind-foot inward, which induces adduction of the fore-foot, elevates the longitudinal arch, and levels the ankle joint.

When the hind-foot is held in a position of inward rotation, the talo-scaphoid and cuneiform-scaphoid joints will remain locked under weight bearing. The arch will not collapse and the ankle will not roll inward.

Correction is accomplished by the specially shaped last. Medially wedged and extended heels promote better weight distribution. Medially extended counters are used for utmost control.



BEFORE AFTER

The Tarso Supinator shoe is used successfully in treatment of the plano-valgus foot. Pronation is controlled at once. Permanent improvements in walking and in foot posture will generally occur. Patients find Tarso Supinators notably comfortable.

Tarso Shoes are ready-made and are available on prescription from dealers in most cities. Write for catalog and name of nearest dealer.

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FOR FLAT FEET

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—*IN* NEUTRILIUM®

NEUTRILIUM® is the most non-corrosive metal known to science. Its proven super-strength lends an assurance of permanence to internal fixation of the trochanteric area. This neutral, non-magnetic, homogenetic alloy is entirely inert and therefore compatible with human bone or tissue, remaining unaffected by body chemistry.

NEUFELD BONE SCREWS — of ***NEUTRILIUM®*** — are cold forged and, unlike other metals, appear to be unbreakable under maximum human pressures. Heads will not twist off during application or in actual use.

GENUINE NEUFELD NAILS and SCREWS — of ***NEUTRILIUM®*** — made only by MEDICAL RESEARCH SPECIALTIES, Loma Linda, California, are sold nationally by leading surgical and orthopaedic supply dealers.

NEUTRILIUM® *is a registered Trade Name of Medical Research Specialties.*

NEUFELD FEMORAL NAIL PLATE
Used for internal fixation of intertrochanteric and subtrochanteric fractures.
Write for descriptive literature.
MEDICAL RESEARCH SPECIALTIES
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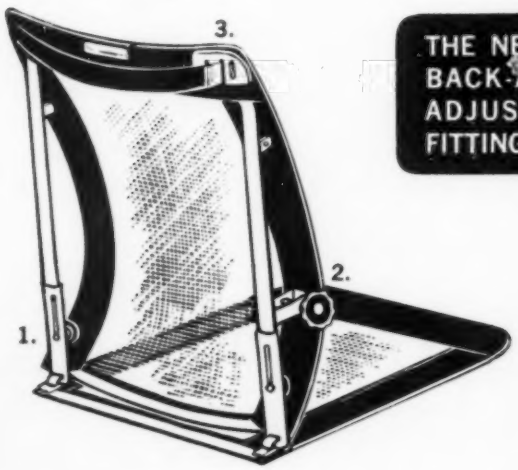
FOR BACK SUFFERERS who drive cars

HERE'S PROPER SPINAL SUPPORT AND FIRM UNDERSEATING



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While seats in the modern automobile are adjustable, there is not sufficient adaptability to the variations in the anatomy of people, their differences in height, body type, and variations in the relative length of their limbs and trunk. The Mark-Fore adjustable Back-Aide, however, can be quickly fitted to and by the individual, and easily readjusted to any changing needs.

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- Shows distinctly all the important bones of the human body.
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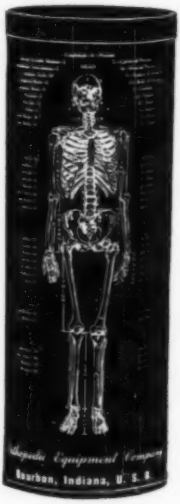
- Shipped fully assembled, in attractive dust-proof crystal-clear display container.



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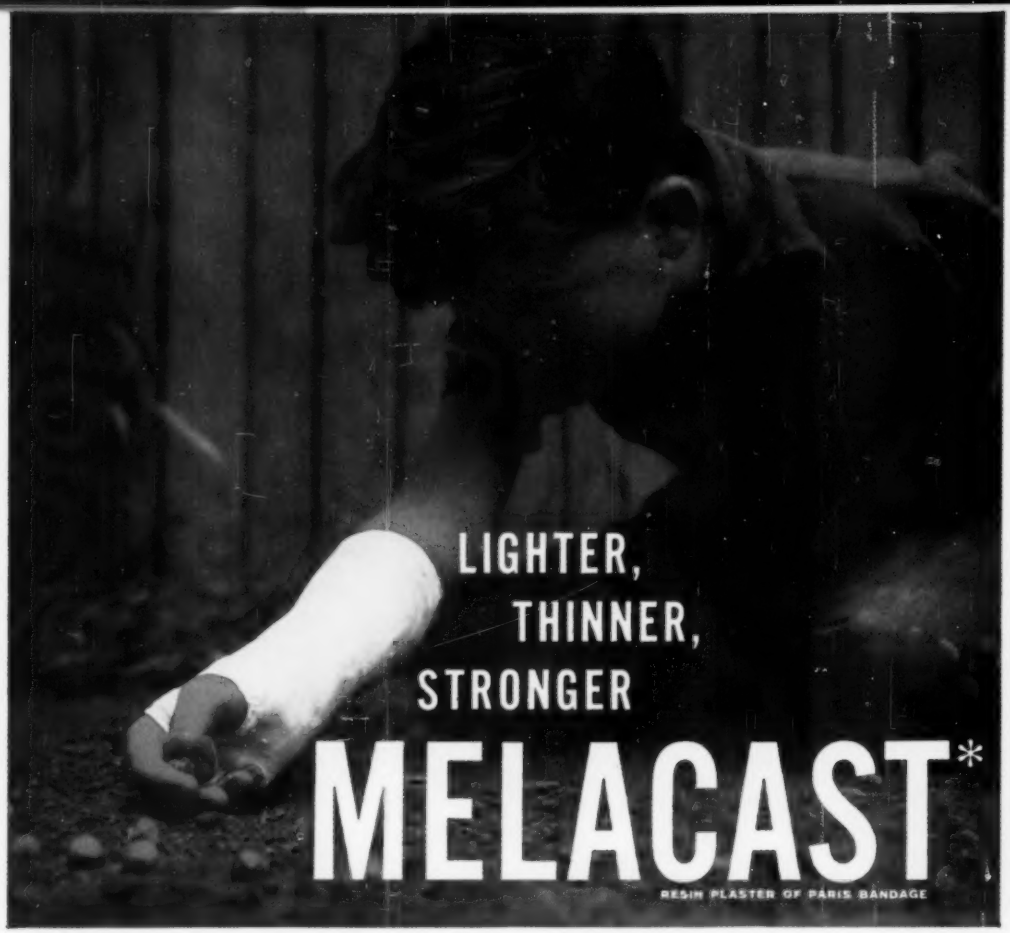
SPLINTS • FRACTURE EQUIPMENT • SMo INTERNAL BONE APPLIANCES • BONE INSTRUMENTS



ready to use just dip, squeeze and apply... requires half as many bandages as ordinary plaster casts

correct drying action no waiting... allows trimming time, then hardens to full strength promptly

makes more comfortable, better looking casts lighter, thinner, smoother... yet much stronger than heavier, clumsier casts of ordinary plaster

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BOYES-PARKER HAND OPERATING TABLE

(U. S. PATENT NO. 2,609,261)

The surgeon and his assistant will find a scientifically designed workbench, efficient and steady, in the Boyes-Parker Hand Operating Table. It eliminates tension and strain during operations. Relieves cramped positions of the hands, arms and shoulders. Space for forearms and elbows improve operative steadiness without tiring, and can thus cut down operating time by 20%.

Removeable stainless steel pan facilitates washing.

Light in weight, easy for nurse to quickly place in position. Adjustable legs allow fitting to any operating table level. Collapsible; requires minimum of storage space.

Pull-out instrument board places instruments in ready position for use.

Formica top; all stainless steel parts; conductive rubber ends on feet.

No. 454	**BOYES-PARKER HAND OPERATING TABLE (Complete with No. 454A Pan)**	**$160.00**
No. 454A	**STAINLESS PAN ONLY**	**16.00**
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RICHARDS ADJUSTABLE SURGERY STOOL

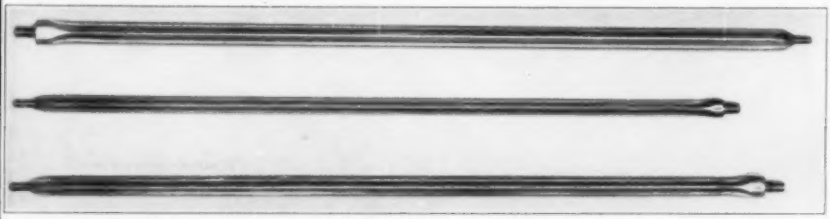
The Richards adjustable stool is designed primarily to be used with the Boyes-Parker Hand Operating Table. Constructed of durable steel tubing, chromium plated. Three legs give stability. The stool embodies the features of an ideal seat for the hand surgeon. The saddle shaped hardwood seat is firm and comfortable, with rounded edges.

The rigid stool does not swivel; there are no casters to slide. Simple and positive up and down adjustment. By sitting on a stool that does not pivot or wobble, the surgeon can maintain an efficient, tireless posture, resting the elbows on the projecting curves of the hand table.

No. 455 SURGERY STOOL.....$55.00

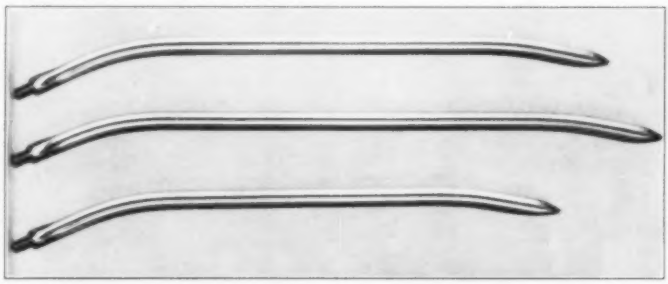
Richards MANUFACTURING CO., MEMPHIS, TENN.

LOTTES NAILS and INSTRUMENTS

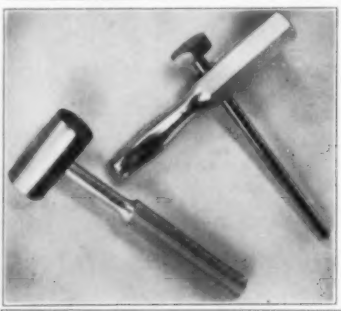


***LOTTES* FEMORAL NAILS** are manufactured with diameters of 3/8, 7/16, and 1/2 inches —with lengths in 1/2 inch variations from 14 to 20 inches.

***LOTTES* TIBIAL NAILS** are made in 5/16 and 3/8 inch diameters—in lengths from 9 to 15 1/2 inches, in variation of 1/2 inch.



***LOTTES* NAILS AND INSTRUMENTS ARE MADE OF 18-8 SMo STAINLESS STEEL**



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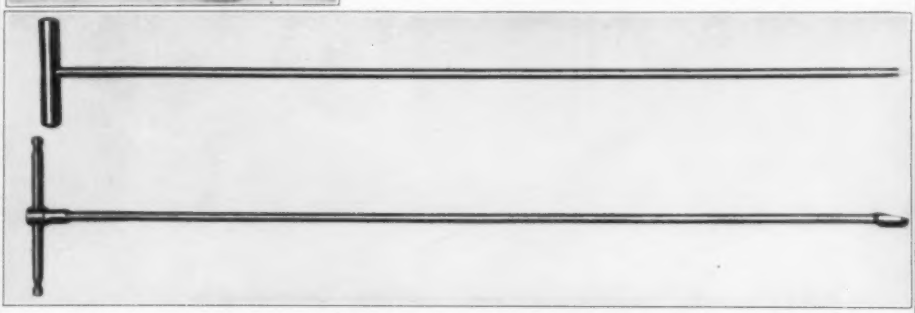
The reamer comes in 3 diameters: 3/8, 7/16, and 1/2 inch—all are 23 inches in length.



CHAS. A. SCHMIDT SURGICAL INSTRUMENT COMPANY
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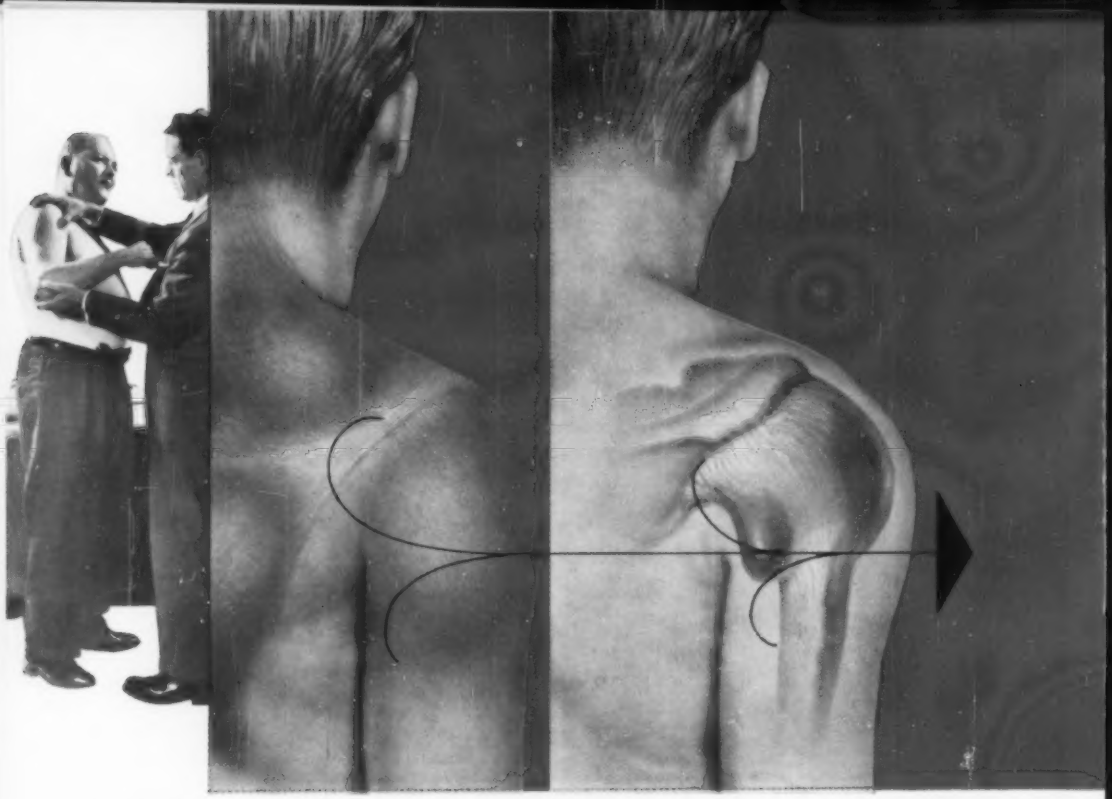
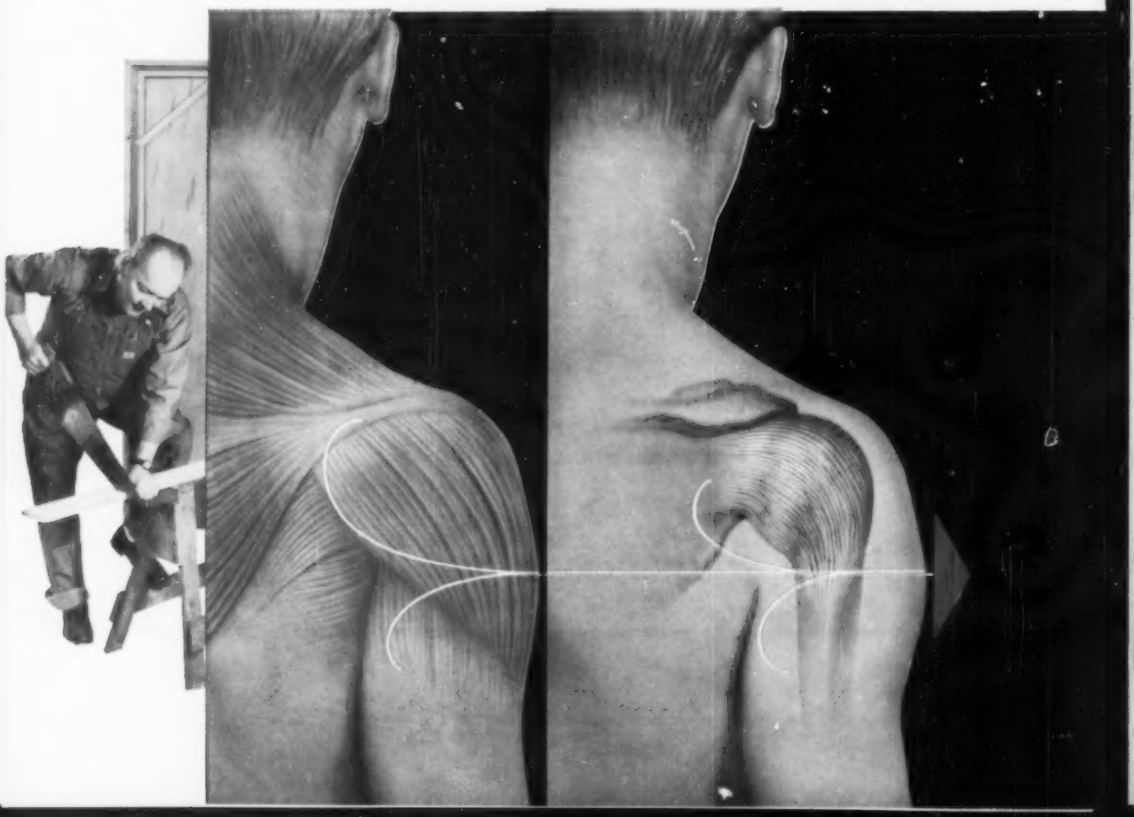


"Rheumatoid arthritis is a constitutional disease with symptoms affecting chiefly joints and muscles."[1] "Pain in the affected joint is accompanied by splinting of the adjacent muscles, with resultant 'muscle spasm.'"[2]



rheumatoid arthritis involves both joints and muscles

only MEPROLONE®

THE FIRST MEPROBAMATE PREDNISOLONE THERAPY

meprobamate to relieve muscle spasm
prednisolone to suppress inflammation

MEPROLONE is the only anti-rheumatic-antiarthritic designed to relieve simultaneously (a) muscle spasm (b) joint-muscle inflammation (c) physical distress . . . and may thereby help prevent deformity and disability in more arthritic patients to a greater degree than ever before.

SUPPLIED: Multiple Compressed Tablets in bottles of 100, in three formulas:
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MEPROLONE-1—supplies 1.0 mg. prednisolone in the same formula as MEPROLONE-2.

1. Comroe's Arthritis: Hollander, J. L., p. 149 (Fifth Edition, Lea & Febiger, Philadelphia, Pa. 1953).
2. Merck Manual: Lyght, C. E., p. 1102 (Ninth Edition, Merck & Co., Inc., Rahway, N. J. 1956).

relieves both muscle spasm and joint inflammation

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Division of MERCK & CO., Inc.

SMO stainless steel drop forged hollow head hip prostheses

neutral position

Austin Moore & Thompson types by Wright

471-M Austin Moore Hip

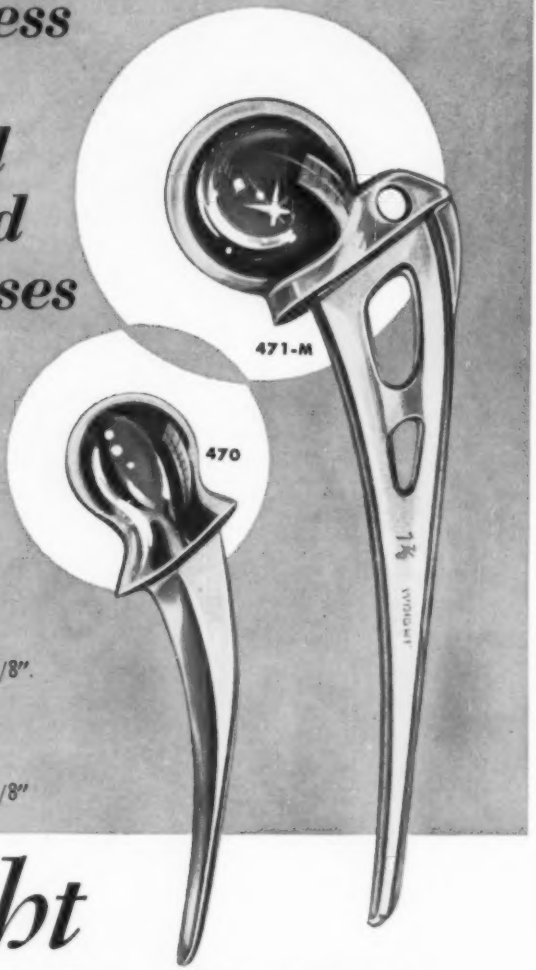
Prosthesis Head Diameter Sizes:

1-5/8", 1-3/4", 1-7/8", 2", 2-1/16", 2-1/8".

470-Thompson Hip

Prosthesis Head Diameter Sizes:

1-5/8", 1-3/4", 1-7/8", 2", 2-1/16", 2-1/8"



Wright

Manufacturing Company

Each prosthesis manufactured by Wright is precision constructed of the finest materials to rigid specifications and must pass the most exacting Zyglo inspection before being released for use. These prostheses closely approximate the anatomical configurations of the femur.

STAINLESS STEEL RASP ASSURES MAXIMUM ACCURACY IN SHAPING HARD INNER CORTICAL BONE OF MEDULLARY CAVITY OF THE FEMUR.

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ARTHRITIC

disorders

HERE ARE THE RESULTS WITH ORAL KENACORT:[1,5]

Number of patients		Daily maintenance dose range (mg.)	Results		
			Excellent or good	Fair	Poor
Rheumatoid arthritis	209	4-24	143	41	25
Rheumatoid fibrositis	1	4-6	1		
Osteoarthritis	23	2-8	6	8	9
Ankylosing spondylitis	1		1		
Rheumatic spondylitis	4	4-16	3	1	
Bursitis	6	4-12	5	1	

KENACORT IS A NEW, IMPROVED CORTICOSTEROID WHICH PRODUCES EXCELLENT CLINICAL RESPONSE

- *with far less gastrointestinal distress* • *without sodium and water retention*
- *without unnatural psychic stimulation*

Scored tablets of 1 mg., bottles of 50 and 500. Scored tablets of 4 mg., bottles of 30 and 100.

1. Reports to the Squibb Institute of Medical Research, 1957. 2. Sherwood, H., and Cooke, R. A.: J. Allergy 28:97, 1957. 3. Hellman, L., et al.: American Rheumatism Association. Interim session, Nov. 23, 1956. 4. Berntsen, C. A., Jr., et al.: New York Rheumatism Association. Annual meeting, April 9, 1957, New York. 5. Freyberg, R. H., et al.: International Congress on Rheumatic Diseases, June, 1957, Toronto.

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Squibb Quality—the Priceless Ingredient

"KENACORT" IS A SQUIBB TRADEMARK.

KENACORT

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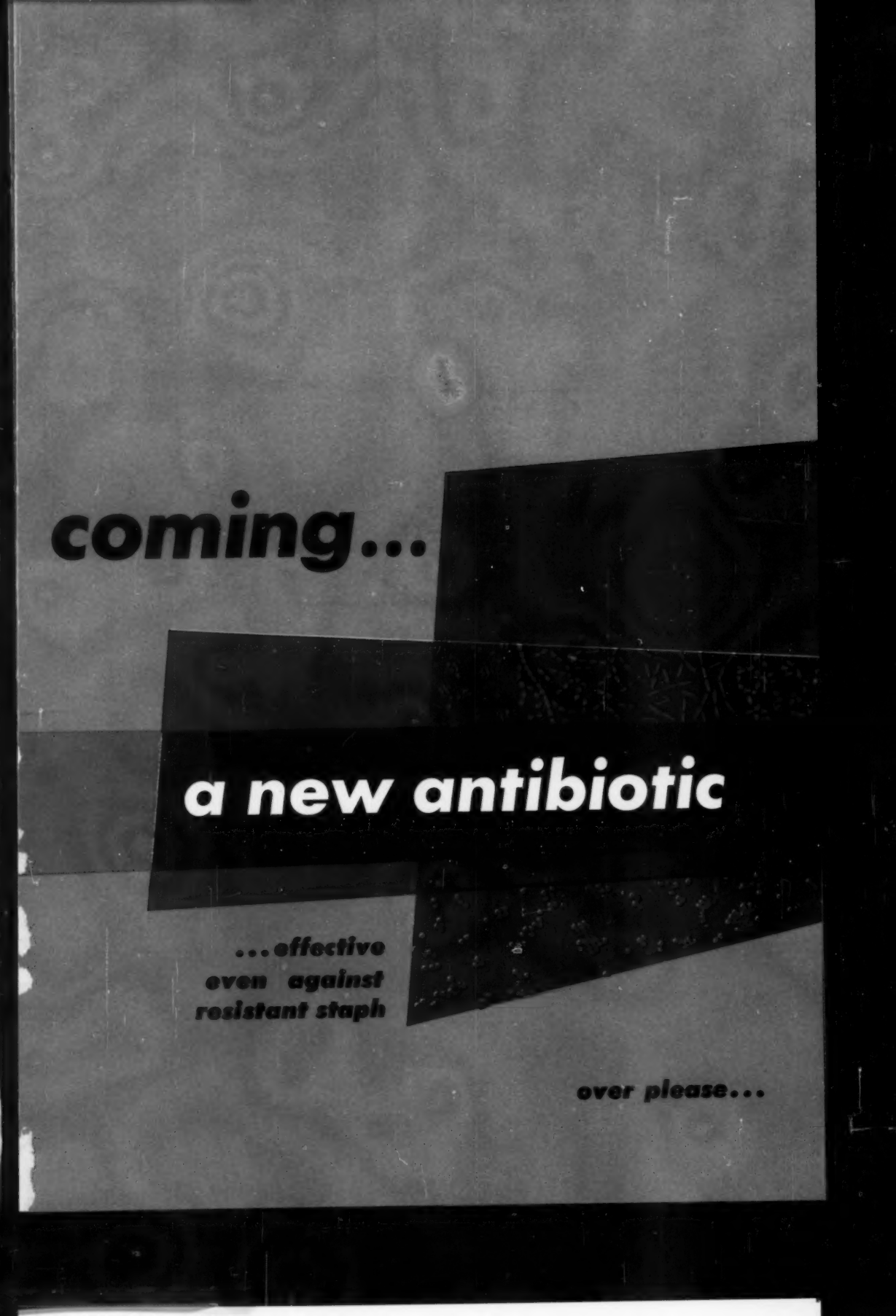
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by
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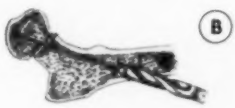
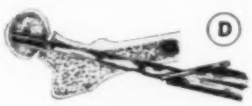
6 A trial film indicates the guide wire of choice to lie on the medial trabeculations in AP film or slightly posterior to midline in lateral film, and a ½" hole is reamed along this wire with a ½" reamer.



7 With the nail fully extended with the inserter in place, the nail and barrel are easily inserted so that the nail approaches the cortex of the proximal fragment. An x-ray is taken.

The plate is thrust distally under the vastus, lateralis, then slipped into place over the grooves of the end of the barrel.



The barrel with the plate attached is driven against the femoral shaft with the impactor. Two screws are inserted. If the nail requires further penetration after examination of the x-rays, this is done.

8 Finally, with all traction removed from both legs, the distal fragment is firmly impacted against the proximal fragment. This results in firm immobility, eliminates interfragment rotation, and seemingly greatly accelerates bone healing.

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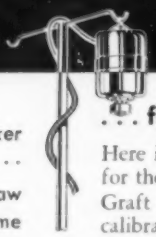

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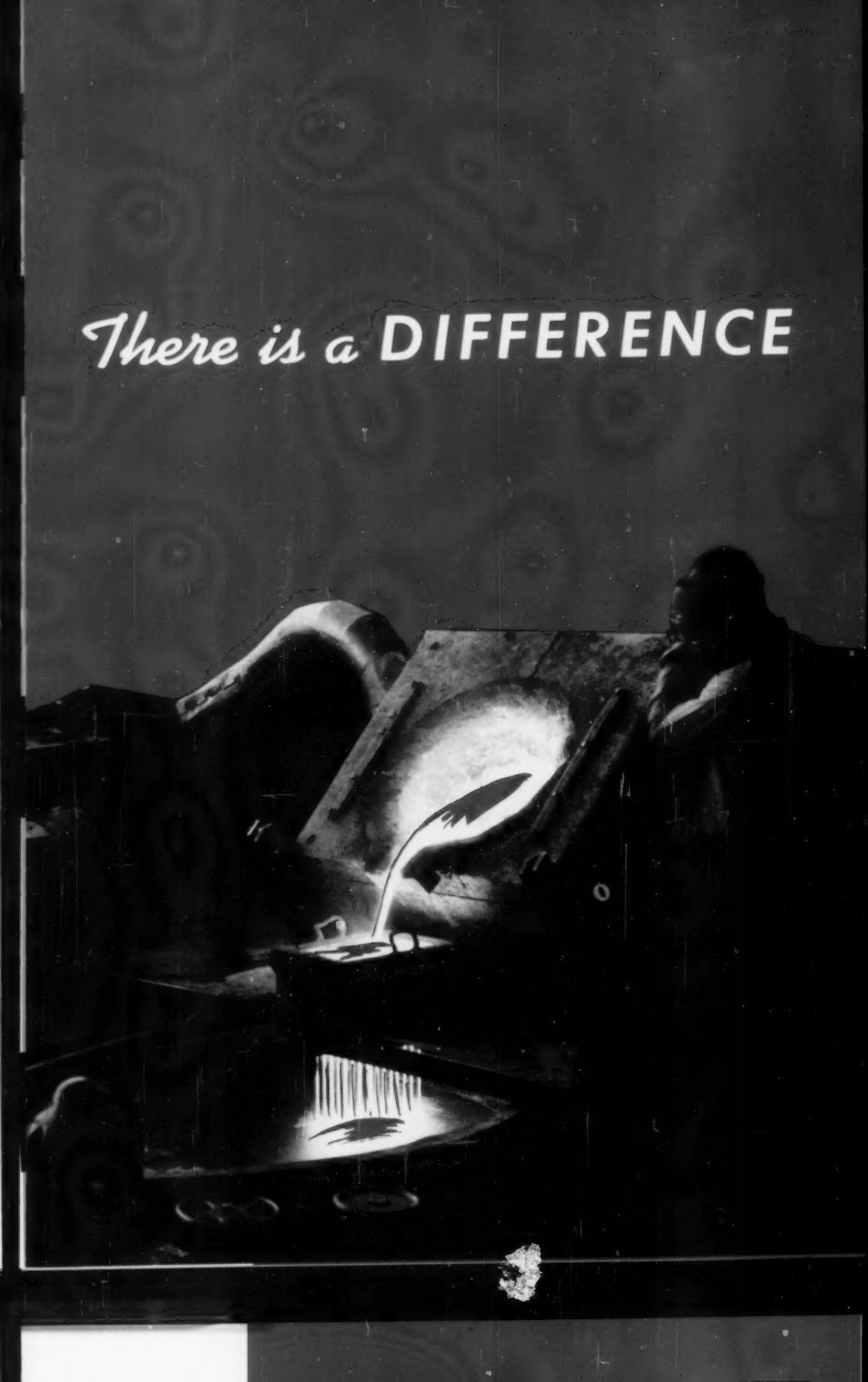
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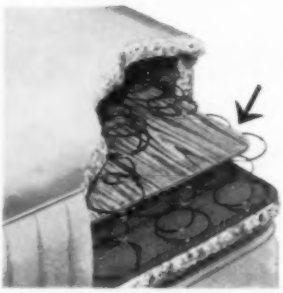

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Technique of Bone Grafting
Metabolic Bone Disease
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Early Examination and Treatment of Injured
Use and Abuse of X-Rays in Fractures
Traumatic Shock
Anesthesia for Injured
Facial Injuries
Craniocerebral Injuries
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Humeral Shaft Injuries
Dislocations and Fractures of Elbow
Fractures of Forearm
Colles' Fracture
Injuries to Carpal Bones
Hand Injuries
Fractures of Pelvis
Fractures and Dislocations of Hip:
  Intracapsular Fractures of Hip
  Extracapsular (Intertrochanteric) Fractures of Hip
  Dislocations of Hip and Fractures of Acetabulum
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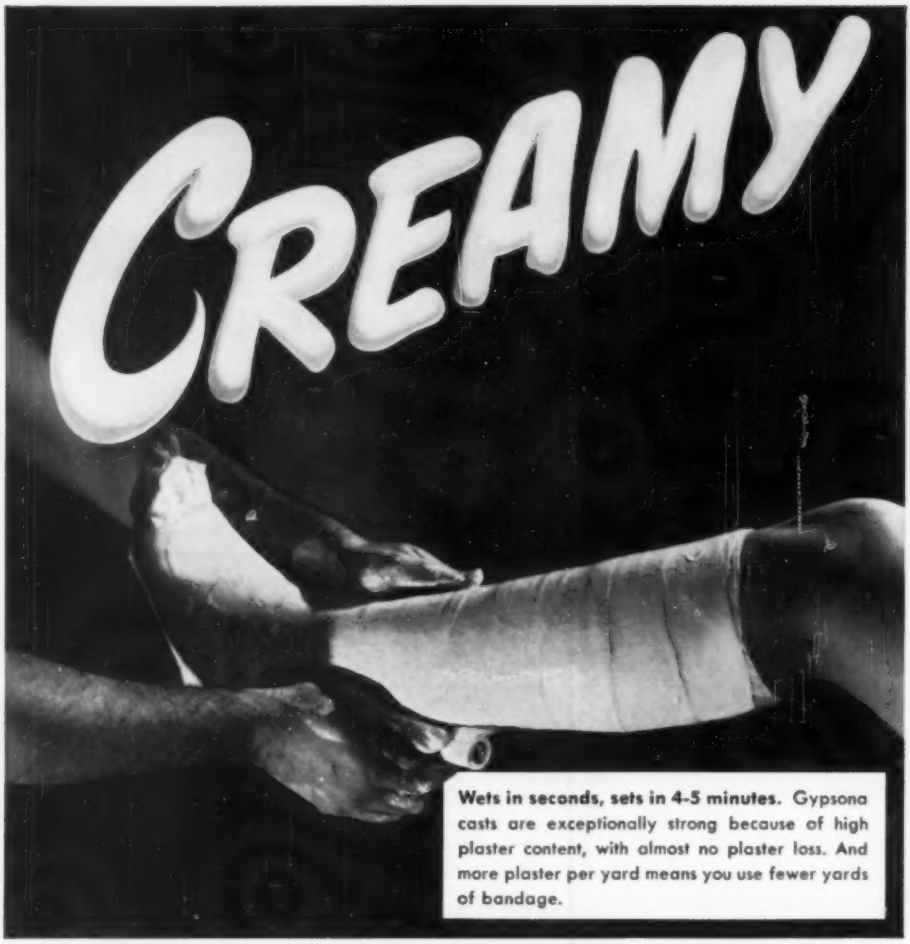
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The Journal of
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American Volume

Scoliosis

EDITORIALS*

The first step in the development of an effective treatment of severe structural scoliosis was the use of spine fusion by Hibbs [2] in 1914. It remained however to devise a means of correcting the curvature satisfactorily before the spine was fused. Many attempts had been made to do this but with indifferent success. The introduction and application of the turnbuckle jacket by Lovett and Brewster [6] and by Ferguson and Risser [3] in the 1920's first provided us with a really efficient instrument for reducing the more severe curves. The jackets were based on the principle that to straighten a curved rod, bending is more effective than traction. This principle had been previously employed by Abbott and others.

The turnbuckle jacket has certain faults, however. As it straightens the primary curve it increases the secondary curves and throws the trunk out of balance. Restoration of compensation later may not be possible. To overcome this difficulty Risser later developed the stabilizer frame in order to reduce the curve and at the same time maintain the alignment of the trunk. Von Lackum [4, 5] accomplished the same end by his transection and later the surcingle jacket. The turnbuckle jacket still is employed in the correction of the more severe deformities, but as a preliminary measure to stretch and render more flexible the deformed segment after which it is removed and one of the newer jackets applied.

Until comparatively recently braces had not been effective in reducing and maintaining correction of lateral curvatures. Now Blount [1, 2] has devised a brace which will do this within certain limits. There is no question that it is successful in the correction of the average scoliosis but it does not seem as effective as the turnbuckle jacket in the correction of the more severe, rigid deformities. The Milwaukee brace is cooler, cleaner, and more comfortable and has the great advantage of permitting the patient to be ambulatory. It calls for the services of a skilled bracemaker, trained in the making of this instrument, and on the part of the orthopaedist, thorough acquaintance with the apparatus and a good deal of mechanical bent. Unfortunately in these days of the extensive employment of surgical procedures in place of mechanical appliances, these qualities are less commonly found in orthopaedic surgeons than they once were.

As experience has been gained in the treatment of scoliosis it has been found that whereas in milder more flexible deformities the secondary curves will reduce spontaneously in proportion to the correction of the primary one, in the more severe cases the secondary curves are irreversible and must be treated as primary ones. This means the application of a corrective force directly to the secondary as well as to the primary curve which may be done either by the localizer frame or by the transection or surcingle jackets in some

* A special editorial on orthopaedic surgery by Frederic C. Bost will be found on page 707.

cases, or by the use of the turnbuckle jacket applied alternately to the two areas in the more rigid ones.

It also developed that although in curves up to 25 degrees almost complete correction was feasible, in those of greater magnitude, forcing the correction beyond certain limits resulted in trouble. In the first place reduction of the primary curve beyond the sum of the secondary curves upsets the compensation and puts the trunk out of balance, and in the second place too much correction of a severe curve cannot be maintained even by spine fusion. Many of our failures in the earlier cases were due to this. In such cases a correction of 50 per cent is about all that should be expected or attempted. Even this degree of correction will bring about a great improvement in appearance and in physiological function if alignment is correct and compensation is achieved.

Once the desired correction has been obtained it can be held by a good spine fusion, provided that in the more severe cases the correction has not been too great. Regardless of what additions or modifications are used, the basis of the operation should be the Hibbs fusion, in which the spinous processes, laminae, and lateral articulations all are included. It is helpful and indeed necessary to use additional bone, but simply piling on a large quantity of this without the preparation of a proper bed beneath is not a substitute for a good operation.

Autogenous bone unquestionably is the best but it is not always easy or feasible to obtain. Bone-bank bone is acceptable as shown by the data reported by Turner, Bassett, and associates [19] of the results with bone sterilized by cathode rays. When a long area of fusion is to be done it is advisable to divide the operation into two or more stages at intervals of two or three weeks. Usually six intervertebral joints are about the limit for one operation. More than this subjects the patient to unnecessary strain and is apt to compromise the thoroughness of the procedure.

In the most experienced hands a certain number of failures of fusion will result. These may not all be primary defects, but may represent fatigue fractures in the fusion plate resulting from strain from overcorrection. There should be constant vigilance for their detection. At each jacket change a careful x-ray examination should be made and if there is evidence of a break in the fusion or if there is localized tenderness over the fusion area with significant loss of correction, the spine should be explored and any defect repaired before greater loss occurs.

In this discussion of the operative treatment of scoliosis we must not lose sight of the fact that all patients do not require jacket or brace corrections and fusion. In many instances progress of the deformity ceases spontaneously before a serious degree is reached. Statistics show that in less than 20 per cent of all scoliosis patients attending a large clinic is jacket or brace correction and spine fusion indicated and that actually only 15 per cent submit to such treatment. The indications for it are first a curve that already has become so great as to constitute a really objectionable cosmetic defect and a threat to the well-being of the individual, and second a progressing curve in a child whose spine will continue to grow for several years.

Accurate records are of the greatest importance in determining the progress of the curve. These should include age, measurements of total height, length of the trunk and lower extremities, and photographs of the patient, as well as x-rays of the entire spine in the standing and lying positions. Mathematical measurements of the curves by the method of Ferguson or by Cobb's modification are also an essential part of the record.

Risser was the first to demonstrate that increase in a spinal curve is associated with growth and that when growth ceases the deformity remains stationary. He also pointed out that the ossification of the iliac epiphyses is an indicator of the growth potential in the spine. It must be realized that during the period of most rapid growth of the spine at and preceding puberty some spinal curves may progress very markedly within a short time. Close and constant observation should be made during this period in order that effective

measures may be taken to arrest and correct the deformity before it is too late to achieve a satisfactory result. In no orthopaedic condition are early detection and treatment more essential than in scoliosis.

Alan DeForest Smith, M.D.

(For references, see page 606)

SCOLIOSIS — QUO VADIS?

At the 1958 meeting of The American Academy of Orthopaedic Surgeons a number of men expressed some concern about scoliosis. The recent enthusiasm for certain braces, plaster casts, and even for the insertion of metallic mechanical devices for surgical correction of scoliosis has added confusion to an already difficult problem. As one member put it, "If those who have worked with scoliosis the most don't agree, what are we, who have to treat these patients only occasionally, going to do?" This is a good question and deserves some consideration.

Many are intrigued by the challenge of scoliosis and people in other fields are interested and contributing their ideas to the problem. (I have communications from people all over the world: a brace invented by an engineer in Istanbul, thoughts on genetics by a zoologist in South Africa, and correspondence with engineers and mathematicians in the United States.)

Scoliosis has always been one of the interesting and difficult problems in orthopaedics. André probably had it in mind when he devised his symbol for orthopaedics. Since then there have been times of renewed interest in this problem. Now we are in another such period. It is stimulating and encouraging but can be confusing to those who have to treat scoliosis patients and do not know which new trend to follow.

With this new interest in the subject great enthusiasm has been aroused. Orthopaedic surgeons are always interested in braces, plaster casts, and mechanical devices; surely many of these have been a great help in recent progress. It is only natural that we should be enthusiastic for some of these appliances. The interest is good and the enthusiasm is promising. But we must consider each phase of the problem thoroughly; carefully weigh each new method, each new device; and we must not misuse a new brace, cast, device, or a new procedure which might have value in certain cases.

For those of us who see scoliosis patients and advise them and advise their parents, it may be helpful to consider some of the ideas of the past, examine those of the present, and peer into the future. Perhaps we might thus prevent the loss of the good and proved methods of the past, encourage the good in the present developments, and stimulate enthusiasm for new ideas in the future.

PAST

There has been great enthusiasm for certain plaster casts, frames, beds, corsets, exercises, and operations. Most of these have been discarded after arousing much hope in some patients only to have it end in despair.

The Abbott frame and plaster cast were once the objects of enthusiasm and the place where they originated became a mecca for those who wished to have or learn the best treatment for scoliosis. Today only a few orthopaedic surgeons even know of the Abbott jacket or frame, now in oblivion.

The Murk Jansen plaster bed, the more recent similar bed of Scaglietti, and the fish-net method (which might be useful in solving certain selected single structural-curve

problems) are seldom used or heard of because, when used to correct one curve in a multiple-curve problem, they tend to increase the opposite structural curves. No one has shown how useful these methods could be in treating selected single curves when there is no concern about subsequent increase in the opposite curves.

Other braces, beds, and plaster casts have been popular and then finally discarded. One very ingenious brace was invented by a man in Denmark many years ago and later rediscovered in the United States. Variations of this brace are still in use.

The Hoke corset was and still is being used for the treatment of post-poliomyelitic scoliosis. It is obvious that one could only expect a corset to support weak abdominal muscles. If it had been used for this, it would still be used more when it is needed.

Exercises have been used for years. In some places they are still liked by those treating, but usually disliked by those having scoliosis. The enthusiast gives exercises to a skinny little girl of eleven, and when she looks better at age sixteen, he thinks it is due to the exercises. Many girls do look better at sixteen. No one has ever shown any x-ray evidence of any appreciable reduction in a significant curvature as the result of exercises. Obviously exercises can be helpful for the posture, and if a patient with scoliosis also has poor posture, the patient may look better if she is given postural exercises. However, when a child is forced to do exercises for the treatment of scoliosis, and then does not note any improvement, and is even told that the curve is worse, it may be doing more psychiatric harm than orthopaedic good.

The abdominal fascial transplant operation was proposed for the treatment of post-poliomyelitis scoliosis and now is seldom, if ever, used even in patients with weak abdominal muscles and a thoracolumbar lordosis in whom it might be beneficial. Time has shown that those of us who said, "One cannot hold up a severe, collapsing, telescoping, unstable, post-poliomyelitic curve by pulling it down," were right.

Resection of congenital hemi-vertebrae has been done and is still sometimes considered. Perhaps the operation lost favor more because the mortality rate in some places was only 50 per cent than because of the realization that it is rarely indicated and is really treatment of the x-rays, not of the patient. A healthy vigorous child with no complaints should not have an unnecessary and possibly dangerous operation or any treatment to convince the parents that "something is being done," or to improve an x-ray shadow. In some cases it might be better for all if the roentgenogram had not been taken.

For a while there were some who resected transverse processes, ribs, or both on the concave side of the curve. I understand that the author of this idea does not do his operation any more. He has a new idea now, but he has not yet told us that the old one did not work.

Stapling operations, used successfully on certain long bones, were tried for a while although it may not have been realized that staples would not be as useful in the spine as in the long bones. If the spine were not growing, the staples might either break or cause pressure changes in the relatively soft bone of the vertebral segments. If the spine were growing, any staple, as a chord across an arc, would help to maintain or increase the arc. It is apparent that staples across a segmented column cannot stabilize the column; one no longer hears about this operation.

So far the only operation for scoliosis that has maintained any degree of correction is a spine arthrodesis. In some cases it seems to have prevented progress of the curve also. This is difficult to prove for two reasons. Many curves may have stopped progressing spontaneously at or before the operation and occasionally curves do increase even after an adequate spine fusion. In general, we may say that an adequate, massive mature and properly located spine fusion will usually maintain some or all correction obtained and there is usually little, if any, further increase in the curve thereafter.

While the spine fusion operation is a fine operation for the few who need it, it will be lost if it is abused. We should not fuse every curve because it might increase. In some

patients, especially those with multiple curves, it may be better to accept a little increase in both rather than to have prevented that increase in one and later have an increase in the other. This would necessitate another operation or the admission that one curve was better and the patient was worse—not as well balanced.

PRESENT

We are now in a period of active investigation. Until we know more about what to do for which patients, and why, and when, it seems reasonable to keep patients with scoliosis under observation during the period when some particular treatment might be indicated. Should we not strive to pick the optimum time to get the best obtainable result through a form of treatment that has been proved?

Time has shown that exercises, braces, and plaster casts will not stop some curves; such will increase despite all.

We do not need more proof that exercises cannot reduce a curve or prevent its increase if it is increasing. Postural exercises are good for posture when needed. We should use them for the treatment of poor posture and not for the treatment of scoliosis.

Plaster casts and braces have their place in the management of scoliosis. Some have proved value for obtaining or maintaining correction when the patient is horizontal. Some that are new are popular and we should reserve decision about their value until there is more known about them. No brace or plaster cast can be expected to be useful in every type of scoliosis. We should not use these new plaster casts and braces for the wrong reasons and thus discredit them.

The present enthusiasm for certain braces and plaster casts has unfortunately encouraged their use for the treatment of scoliosis. This is helpful for those who must do something—even if it is harmful, but it is confusing for those who do not know which to choose or why. Obviously there can be no panacea for scoliosis. No particular brace or plaster cast can prevent any increase in every type of scoliosis. When there is instability, discomfort or pain, or need for reducing a curve, plaster casts or braces may be helpful. They may be useful for maintaining a spine in position until bone fusion is adequate.

At present, it seems reasonable, too, to observe any patient with scoliosis during the time when the curves might increase despite treatment. During this observational period one could search for the etiology of the curve; more study could be directed to the natural history or course of the disease.

While any patient with scoliosis due to neurofibromatosis should be seen at least once a year until the age of twenty, and any patient with a history of poliomyelitis should be examined at least once a year for ten years, or until age sixteen, whichever is longer, most other types of scoliosis need no further observation after age sixteen.

Parents are usually relieved to know that many scoliosis patients need no treatment. Since the majority need no treatment, we may help more of these young people by knowing when not to than how to treat them.

Many parents have a feeling that they or someone should have noted their child's curvature sooner when something could have been done. With our present knowledge, the earlier discovery of most cases would only have given the parents a longer time to worry about it.

Most parents are also relieved to know that there is an end point to the scoliosis problem. When the patient has reached fifteen or sixteen and there is a sequence of three sets of roentgenograms showing no further significant change, it hardly seems necessary to have any more made, unless there is a possibility of neurofibromatosis or poliomyelitis.

In a patient with scoliosis, when the first roentgenograms are made, it is desirable to make anteroposterior roentgenograms with the patient standing and sitting and a lateral roentgenogram with the patient either standing or sitting. The anteroposterior roentgenograms made with the patient standing and sitting may be repeated in not less than three

months and usually not more than twelve months, depending upon the age of the patient.

It has been estimated that there is less roentgen exposure in the few films actually needed for the adequate study of a scoliosis patient than in a routine fluoroscopic chest examination. In the younger patients with mild curves in the idiopathic group, under twelve years of age, when there has been no change and none is expected, it may be reasonable to wait four, five, or even six months before repeating a set of roentgenograms. Perhaps a good rule in this group is not to repeat them sooner than three months because it isn't necessary.

Today there are enthusiastic supporters of mechanical appliances of metal introduced at open operation for the internal correction of scoliosis. It is obvious that metal fastened to bone may hold bones or parts of bones in a certain position for a time. Certainly one cannot expect osteogenic properties in them. Ultimately, unless something else is done to stabilize the vertebral segments in an unsegmented form, there will be bone erosion, or the device will slip or break if intervertebral motion is allowed to persist. One wonders if these devices will stand the test of time. They are now on trial and have yet to prove their worth.

It must be remembered that many spine curves are mild and few need any treatment. Many may go unrecognized. Realization of this may save the patients and their parents a lot of unnecessary treatment and worry. Few patients with scoliosis need treatment, their parents need a lot. Few methods of treatment for scoliosis have survived any significant time. A little sensible reassurance to the patient and her parents is better than a lot of unnecessary, inadequate, and expensive so-called treatment. On the other hand, curvatures that may progress until they seriously deform the child must be recognized and demand our best efforts.

So far the only treatment that has prevented increase or maintained any correction in a curve is spine fusion but this is indicated in a relatively small number of cases. Usually the results of various treatments for scoliosis seem to be directly proportional to the enthusiasm of the one treating or the one being treated.

It seems important to emphasize to the parents that there is more chance the curve will not need treatment than that it will. Usually the patients whose curves increase tend to go back to the doctor, while those whose curves do not increase are satisfied to carry on without doing anything about it.

FUTURE

While the problem of scoliosis is difficult, it can be interesting and will of course, like most problems, ultimately be solved.

With the renewed interest in the problem of scoliosis and the research and study to be expected in the future we can of course expect great progress. We know a good deal about poliomyelitic scoliosis and that due to congenital variations and to neurofibromatosis and we know some practical things about the problem of the great miscellaneous group, idiopathic scoliosis. There must, however, be more study to determine the various subgroups in the idiopathic group. At present we must follow our patients through our roentgenographic schedule and recognize internal changes in their curves as soon as possible after they have occurred. In the future, we will undoubtedly have some test or tests which will indicate which curves are likely or more likely to increase, thus this increase could be anticipated and prevented rather than treated after it has occurred. In the future study of scoliosis it will be necessary to keep our eye on the patient and not on the curve.

John R. Cobb, M.D.

The Milwaukee Brace in the Operative Treatment of Scoliosis *

BY WALTER P. BLOUNT, M.D., ALBERT C. SCHMIDT, M.D., E. DUDLEY KEEVER, M.D., AND EUGENE T. LEONARD, M.D., MILWAUKEE, WISCONSIN

The Milwaukee brace was first described by the senior authors at the meeting of The American Academy of Orthopaedic Surgeons in January 1946 (Fig. 2-C). Although information regarding this appliance has been supplied on request, the technique and results have not yet been published in the United States. After twelve years' experience a simplified brace can be proffered (Fig. 1-A). Although the principles remain unchanged, our procedure has been improved and standardized [1]. Follow-up studies have suggested modification of the operative technique to avoid pseudarthrosis, the greatest problem with any method. We are now presenting the operative method, results, and our comments.

FIG. 1-A

Case 1. An eleven-year-old boy with right thoracic paralytic scoliosis corrected by a Milwaukee brace eighteen months after the onset of poliomyelitis. (Reproduced by permission from "Conquest of the Crooked Back" by Walter P. Blount, *The Crippled Child*, **34**: 6, Apr. 1957.)

The Milwaukee brace was developed as a refinement of the distraction [14, 15] or transection plaster jacket [8]. In many ways it is an improvement over the turnbuckle jacket [12] and combines the most effective forces used in the correction of scoliosis. The principles of the Milwaukee brace have recently been embodied in the localizer cast [13]. This is preferable when there is no capable and cooperative bracemaker available. In our hands the brace is more adaptable than the cast, equally efficient, and more comfortable. Rarely, when we fear that the parents will readjust the brace without permission or remove it prematurely, we use the localizer cast. Otherwise we see no advantage in using plaster.

Mr. Richard Bidwell [2] is responsible for the execution of the following significant changes in our brace. The iliac crests are accentuated and the waist is constricted so that the pelvic girdle rides on top of the crests and does not press against the sides of the pelvis (Fig. 1-A). This eliminates pressure sores. By filling out the plaster positive on the concave side, the pelvic girdle is fashioned to fit the torso after correction of the curve.

Turnbuckles have been eliminated. Extension of the brace is obtained by elongating the overlapping upright bars, the principle that is used in most leg braces †.

* Read in part at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1957.

† An improvement has been suggested by Mr. William M. McDonald. Each of the two posterior upright bars is quickly adjusted by engaging a fixed pin in one of a series of numbered holes. The halves are kept from separating by two sliding rings which slip easily into place and are held securely by set screws. This simplifies application of the brace in the operating room and postoperative adjustment.

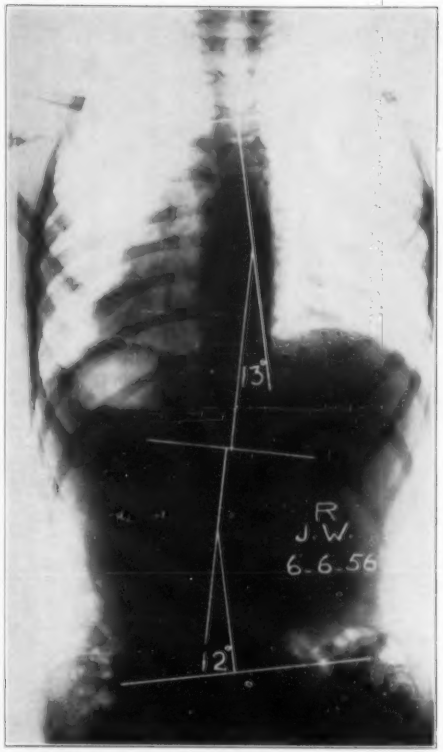

FIG. 1-B

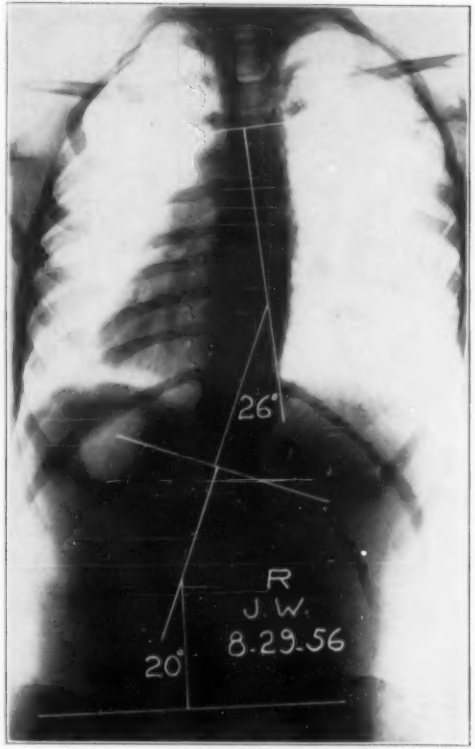

FIG. 1-C

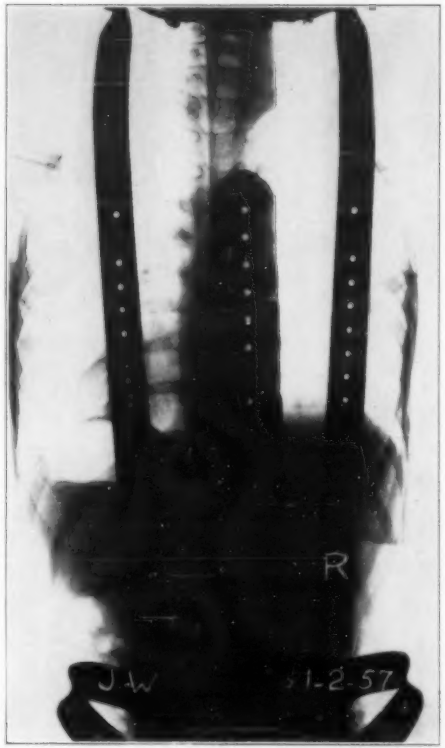

FIG. 1-D

Fig. 1-B: Roentgenogram made with the patient standing when the curvature was first noticed ten months after the acute attack of poliomyelitis. (Reproduced by permission from "Conquest of the Crooked Back" by Walter P. Blount, *The Crippled Child*, **34:** 6, Apr. 1957.)

Fig. 1-C: Roentgenogram made with the patient standing three months later showing rapid progression. (Reproduced by permission from "Conquest of the Crooked Back" by Walter P. Blount, *The Crippled Child*, **34:** 6, Apr. 1957.)

Fig. 1-D: Roentgenogram was made with the patient standing in the brace six months after that in Fig. 1-C. The brace holds the scoliotic spine in a corrected position. It allows vigorous exercise at school, and was removed for swimming. Six months later it was removed all day without loss of correction. (Reproduced by permission from "Conquest of the Crooked Back" by Walter P. Blount, *The Crippled Child*, **34:** 6, Apr. 1957.)

The pressure pad is fixed to a single, heavy, broad leather strap which is secured to the uprights at any desired level by truss studs. Great flexibility of adjustment is obtained by moving the pad up or down, backward or forward. By placing the strap over, instead of under, the posterior bar on the convex side, pressure is applied directly from the lateral side. By attaching it to an outrigger on the front bar, pressure on a breast is avoided.

Very early we changed the cupped chinpiece to a padded mandible support which permitted free protrusion of the jaw. Since then we have not had an increase in overbite [2]. Dental models were made as a record before starting treatment. These were compared with the jaws after the Milwaukee braces were removed.

In three cases, we tried the tilting headpiece as recommended by Irwin. Each patient asked to have the fixed chin and occiput support replaced. With the immobile headpiece, a patient can relieve the chin for chewing or brushing teeth by transferring the support to the back of the head. Adequate force can be tolerated better by alternating it from chin to occiput or to the pressure pad with complete freedom of chin and occiput. One can readily understand how a patient would develop a considerable overbite from the constant pressure and prolonged use of a tilting, cup-shaped chinpiece.

The essential metal parts, except for the pelvic girdle, have been prefabricated in the interest of economy. The pelvic girdle must be molded for the individual patient. When the patient's weight changes, or the pelvis is very oblique, the girdle must be remade after partial correction of the deformity.

At first, the Milwaukee brace was used only in the treatment of thoracic curves which were to be fused after correction. More recently, with suitable modifications [2], it has been found effective in the improvement of almost any spinal curve. We now wait to obtain most of the correction after the operation. When pelvic obliquity is a factor, a leg frame is added with a ratchet for skeletal traction on one side and an elastic upward pull on the other, according to the Hoke traction principle [2]. In individual cases the pelvic girdle is greatly modified to permit the treatment of grotesquely deformed spines which cannot be handled successfully by another method (Fig. 5-A).

In recent years we have come to use the brace sparingly in the non-operative management of scoliosis. We mention the conservative management here in order to warn that it should be used only in three clearly defined situations.

1. When the existing idiopathic deformity is still acceptable in an adolescent, near the end of the growth period, a rapidly progressive curve may sometimes be reduced 25 per cent or more and held until growth is completed. When the brace is removed there will be some loss of correction. The curve will have become compensated, however, and usually the curve itself is slightly improved, not worse as it probably would have been without the brace. If a curve is not acceptable to begin with, satisfactory improvement is rarely obtained by conservative treatment. If a curve progresses while the patient is ambulatory in a Milwaukee brace, it should be fused.

2. In a few convalescent poliomyelitic patients with functional or very early structural scoliosis, the Milwaukee brace has aided in reducing the curve and holding it in check until muscle balance has been re-established (Fig. 1-D).

3. In patients with chronic poliomyelitis and abdominal weakness, the brace has been found most efficient in the conservative treatment of scoliosis combined with pelvic obliquity. Various types of operations to release the fascia lata and to insert abdominal fascial transplants have been used to correct the pelvic deformity. During rehabilitation the brace has splinted abdominal muscles after their functioning segments have been reactivated by fascial tethers. The untouched mobile spine is often a great advantage in crutch-walking.

As an adjunct to surgery, the patient wears the brace before operation only long enough to become accustomed to it, usually one to three weeks. Most of the correction

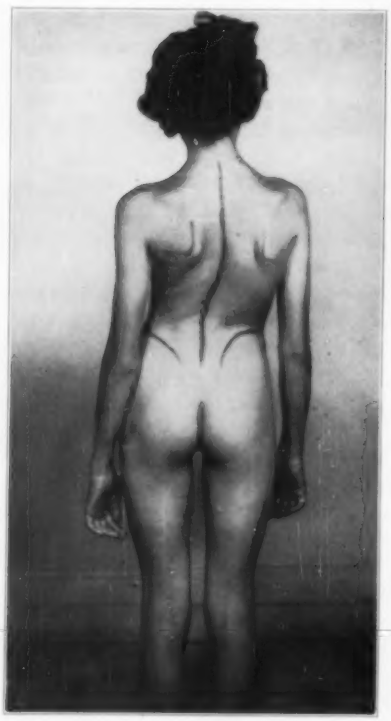

FIG. 2-A

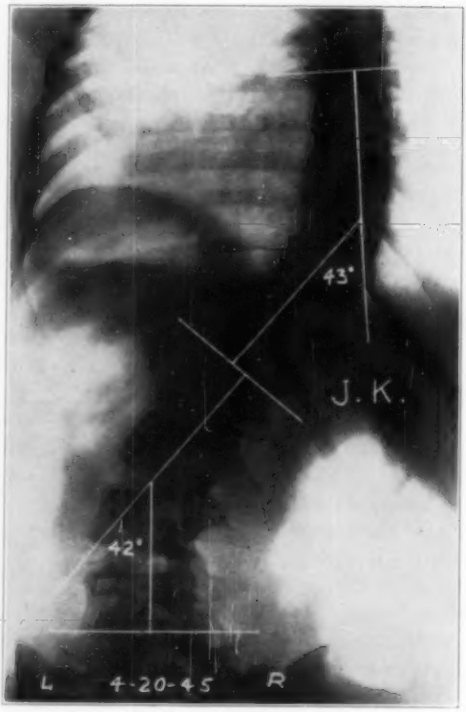

FIG. 2-B

Fig. 2-A: Case 2. An eleven-year-old girl with paralytic scoliosis of several years' duration. She had poliomyelitis at the age of three. The flexible curve increased from 25 degrees to 43 degrees in one year. (Reprinted by permission from "The Treatment of Scoliosis" by W. P. Blount. *Sixième Congrès International de Chirurgie orthopédique*, p. 225. Bruxelles, Imprimerie Lielens, 1955).

Fig. 2-B: The 43-degree curve in a roentgenogram made with the patient standing just prior to application of the original Milwaukee brace and fusion of the spine.

Fig. 2-C: In 1945, the Milwaukee brace was opened at the back to permit surgery with the brace *in situ*. This patient was allowed to walk two months after surgery. Now the pelvic girdle (Fig. 1-A) is deeply molded over the iliac crests. Posterior closure is almost complete. The brace is removed for a second operation and reapplied in the operating room. The patients are kept recumbent for from four to five months.

Fig. 2-D: In the roentgenogram made with the patient standing two years after removal of the brace, this quadruple curve is well corrected. The compensatory lumbar curve is equal to the fused thoracic curve. The low lumbar and upper thoracic curves are symmetrical.

Fig. 2-E: Ten years later, the correction is maintained.

Fig. 2-F: Photograph made two years after discarding the brace. The torso is compensated and the back looks straight. The same was true ten years later.

of the resistant curves is accomplished after surgery (Fig. 5-D) when contracted muscles and ligaments have been removed, and congenital bars of bone have been osteotomized. Necessary adjustments should be made before rather than after the operation. If any pressure areas appear, or if the patient is uncomfortable, the brace is removed by unbuckling a strap and removing ten screws. Interruption of brace fixation is rarely necessary in children. Adults adjust to the brace gradually and must wear it for a longer time before they are ready for surgery. The brace must not be too easy to remove.

When the contact areas are accustomed to the pressure of the brace, the patient is admitted to the hospital at least two days prior to surgery. Even though the brace becomes loose with recumbency, there is usually considerable improvement of the scoliosis.

FIG. 2-C

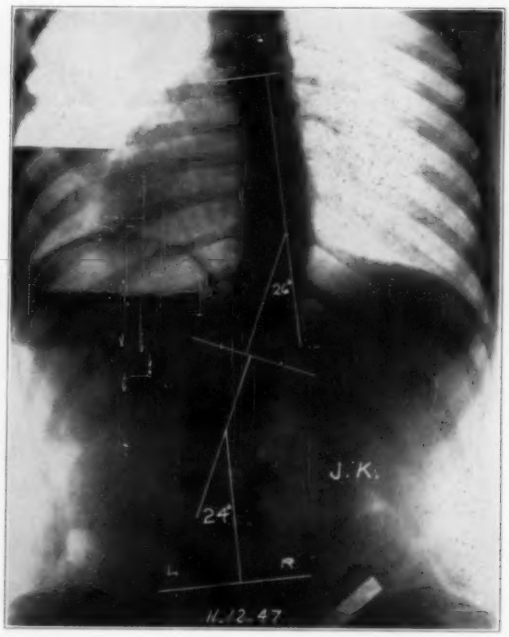

FIG. 2-D

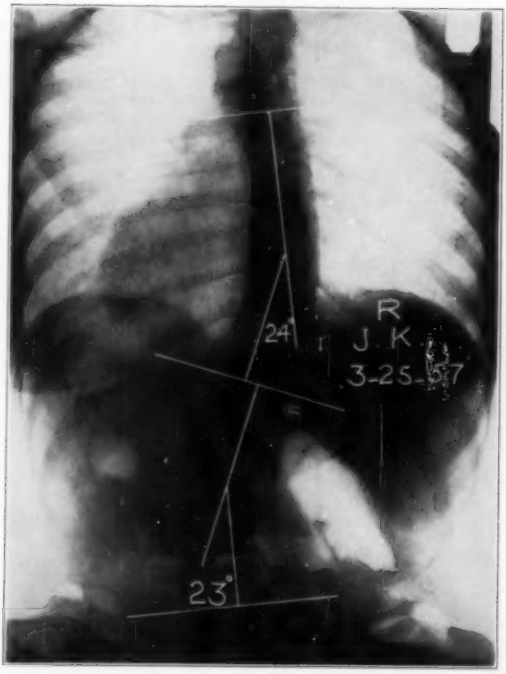

FIG. 2-E

FIG. 2-F

FIG. 3-A

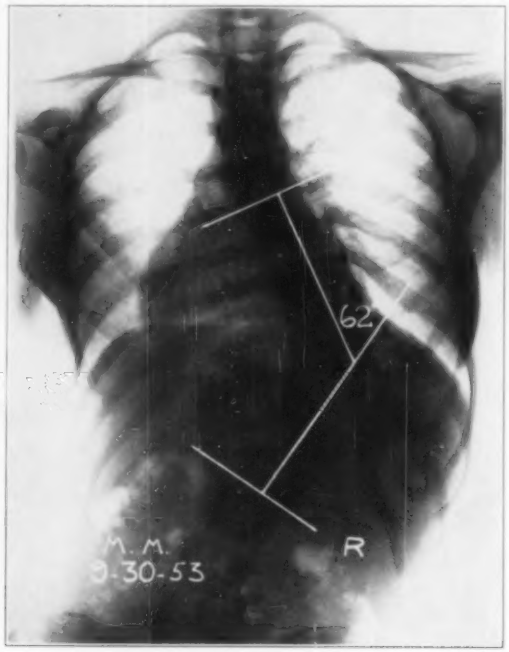

FIG. 3-B

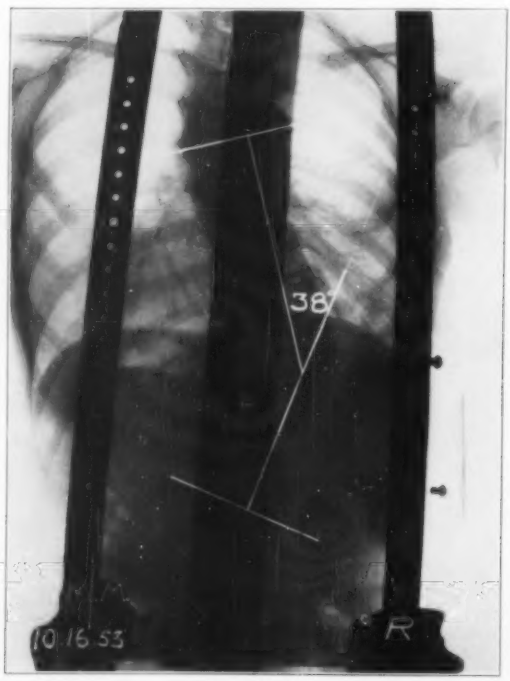

FIG. 3-C

Fig. 3-A: Case 3. A twelve-year-old girl with idiopathic scoliosis that was first noticed one year before treatment with the Milwaukee brace and fusion.

Fig. 3-B: A roentgenogram made with the patient standing shows a right thoracolumbar curve of 62 degrees with a shift of the trunk to the right. There are structural changes in both the major curve and the upper compensatory curve.

Fig. 3-C: A roentgenogram made with the patient standing after applying the Milwaukee brace. Compensation has been obtained and the curve was reduced to 38 degrees.

The brace may be removed on the evening before surgery, and the patient given a bath.

THE OPERATION

In the operative fusion of a scoliotic spine the following points are of great importance:

1. The incision must be along a straight line between the spinous process of the seventh cervical vertebra and the mid-sacrum (Fig. 3-E). With the anaesthetized patient prone, forceful traction is made on the head and feet, and a preliminary scratch

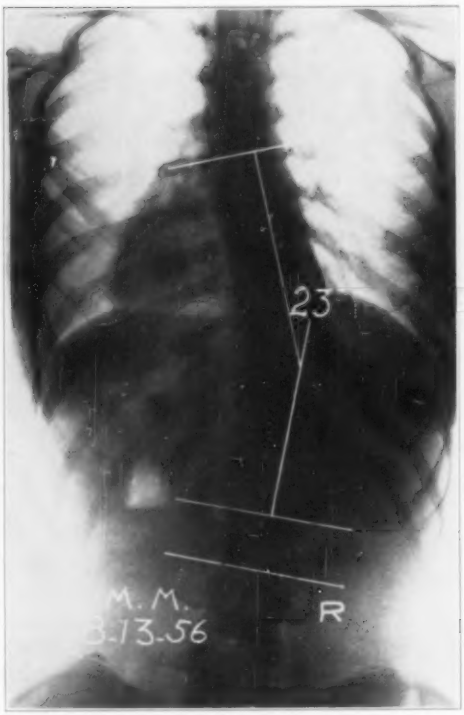

FIG. 3-D

FIG. 3-E

Fig. 3-D: A roentgenogram made with the patient standing three years after fusion of the sixth thoracic through the second lumbar vertebra, shows good maintenance of the correction. The solid bone column is visible.

Fig. 3-E: Three years after correction and fusion there has been no relapse of the curvature. Rotation is almost completely corrected.

is made on the skin with the back of a knife beyond the probable limits of the incision.

2. Accurate identification of the level is imperative. A postero-anterior roentgenogram with a marker is made in the operating room. A curved needle threaded with a short piece of black silk is easily identified in the tissue. It is inserted between two low thoracic spinous processes and it is not removed until these processes are exposed and identified.

3. Subperiosteal exposure of the spine should be carried laterally as far as the cartilaginous caps on the thoracic transverse processes. In the lumbar region the facets are exposed.

4. All of the articular facets should be methodically fused except in cases of extreme rotation when some of the facets on the convex side are inaccessible because they are covered by the acutely angulated ribs. It is most important to develop the transitional joints between the eleventh and twelfth thoracic vertebrae.

5. Cancellous bone must be exposed over the stumps of the spinous processes, laminae, and thoracic transverse processes. This may be done by turning cortical slivers from adjacent segments. If they are left attached at one end they may be interlocked according to a regular plan.

6. Autogenous bone is almost always added; it is always added in fusions extending below the eleventh thoracic vertebra. This is best obtained from the ilium through an extension of the primary incision along the mid-line skin scratch to the mid-sacrum. The skin and subcutaneous tissues are easily retracted to one side. The bone is exposed by in-

FIG. 4-A

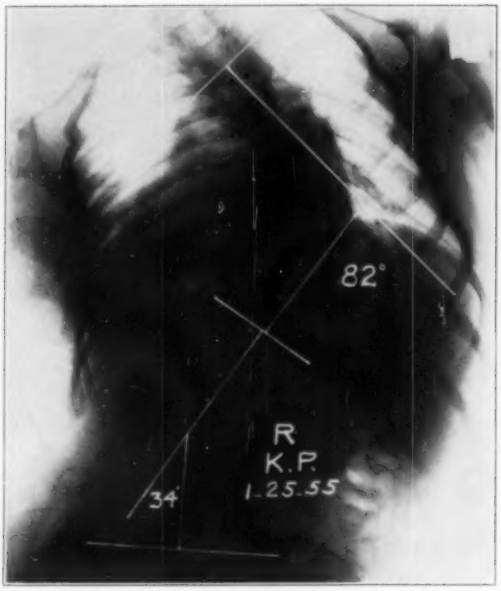

FIG. 4-B

FIG. 4-C

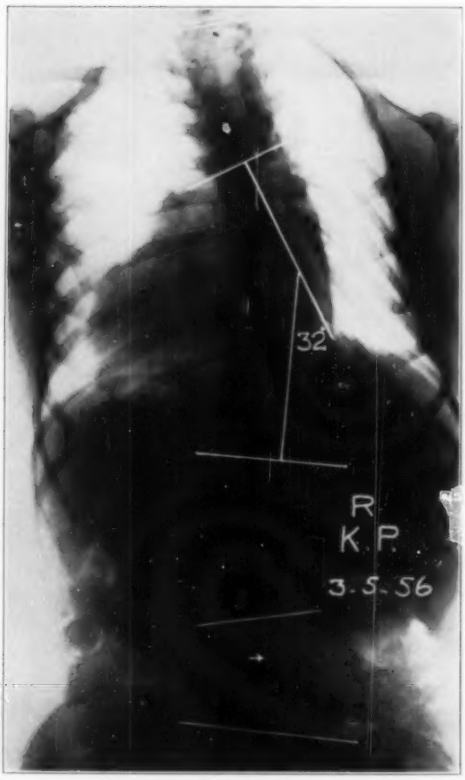

FIG. 4-D

Fig. 4-A: Case 4. A girl, five and one-half years old, with a decompensated right convex curve which followed poliomyelitis at age one. There is thoracic lordosis. (Reproduced by permission from "Conquest of the Crooked Back" by Walter P. Blount, *The Crippled Child*, **34**: 7, Apr. 1957.)

Fig. 4-B: A roentgenogram made with the patient standing shows a markedly decompensated right low thoracic curve of 82 degrees with early structural changes. Application of the Milwaukee brace only partially corrected the curve.

Fig. 4-C: The patient started walking in the brace four months after fusion of the spine. Much of the thoracic lordosis has been corrected by the operation and the distraction of the brace. The outrigger is used to direct the force of the pad medially without any component in the forward direction. The girdle has spread to allow for enlargement of the pelvis. (Reproduced by permission from "Conquest of the Crooked Back" by Walter P. Blount, *The Crippled Child*, **34**: 7, Apr. 1957.)

Fig. 4-D: A roentgenogram made with the patient standing shows the correction of the major curve to 32 degrees after fusion and postoperative fixation with the Milwaukee brace. The solid column of bone from the first thoracic to the third lumbar vertebra is identified by markers. Note that there is an increasing shortening of the right leg. The length will be equalized early, after eight years of age.

Fig. 4-E: Ten months after the spine fusion. A follow-up examination one year later showed the same appearance. (Reproduced by permission from "Conquest of the Crooked Back" by Walter P. Blount, *The Crippled Child*, **34**: 7, Apr. 1957.)

FIG. 4-E

cising the fascia along the iliac crest. With this approach there is no danger of marginal necrosis from pressure of the pelvic girdle. The postoperative pain at the donor site is minimal, and there is no annoying postoperative cutaneous anaesthesia.

Homogenous bone is less desirable for use in fusion. If it is used in children to augment the bulk of the graft, small quantities should be added. A large mass predisposes the fusion to pseudarthrosis.

7. Shock must be prevented. This implies attention to many factors including the service of a skilled anaesthetist, and the prompt replacement of blood. Trauma may be reduced to a minimum by using a light mallet, keeping all cutting instruments sharp, and handling tissues gently. Accurate knowledge of the anatomy at every level is necessary to avoid excessive loss of time and blood in the identification of the facets. The beginner would do well to hang an articulated spine in the operating room.

8. The fusion area must be carefully determined. There are many factors to be considered. The variables include the age of the patient, the correctability of the curve, the cause of the curvature, and associated physical findings and mechanical problems.

There is no substitute for experience. The fusion area in patients with poliomyelitis is frequently between parallel vertebrae, the maximum fusion area, or it may include all of the thoracic and cephalad three or four lumbar segments (Fig. 4-D). In some patients with idiopathic curves, it is enough to include only the primary curve, that is, the minimal fusion area. In others, it may be necessary to add more segments. The orthopaedist who is not thoroughly familiar with the treatment of scoliosis should start with the simpler cases and as he gains experience, undertake the more complicated ones. Consultations are desirable.

We are convinced that the following aphorisms are sound. (They have the approval of most of the members of the Scoliosis Committee of The American Academy of Orthopaedic Surgeons.)

1. Paralytic curves with extensive weakness of the trunk, causing respiratory embarrassment, are usually best fused without temporizing from the first thoracic to the third or fourth lumbar vertebra in two or three stages (Fig. 4-D).

2. An unacceptable curvature of the spine that becomes progressively worse in spite of efficient conservative management should be fused without regard for the age of the patient.

3. Fusion of the spine in a growing child will somewhat restrict longitudinal growth. It is better, however, to have a moderately short straight torso than a very short crooked one. The mechanical lengthening of the spine obtained by correcting the curve usually exceeds the future restriction of longitudinal growth.

4. Significant progressive thoracic lordosis has not been observed following spine fusion. A flat or lordotic thoracic spine is frequently found in scoliotic patients with rotation of the vertebrae, particularly after partial correction of the curve by side bending. This flat back often rounds out again after operation and the use of the Milwaukee brace.

FIG. 5-A

FIG. 5-B

Fig. 5-A: Case 5. Roentgenogram of a woman, twenty-nine years old, while standing. Poliomyelitis at the age of two left the patient with a left thoracic, kyphoscoliosis curve of 187 degrees with 80 degrees of rotation. She had had no support except a corset. The respiratory embarrassment was so great that she could not walk more than a block or two and she could not stand or sit for more than two hours without excessive fatigue and back pain. Employment was impossible. (Reprinted by permission from *Grundlegenendes über die Skoliose und ihre Behandlung* by A. C. Schmidt. Verhandl. d. Deutschen Orthop. Gesellsch., 41 Kongress, 195, 1954.)

Fig. 5-B: Two years after partial correction with the Milwaukee brace, rib resection on the side of the concavity, and four-stage fusion on the side of the concavity with autogenous iliac and rib grafts from the first thoracic vertebra to the sacrum. Subsequent exploration showed that the graft was solid. A four-inch gain in height required the use of skull tongs to permit removal and remaking of the brace between stages. The patient's respiratory function was greatly improved, and she was able to work steadily. (Reprinted by permission from *Grundlegenendes über die Skoliose und ihre Behandlung* by A. C. Schmidt. Verhandl. d. Deutschen Orthop. Gesellsch., 41 Kongress, 195, 1954.)

POSTOPERATIVE CARE

After completion of the fusion, the brace is reapplied. The patient is lifted from the operating table in the prone position while the pelvic girdle is spread and slipped on with the front bar and chinpiece attached. With the patient still prone, the halves of the headpiece are united with four screws and the back bars joined. Then the pressure pad is added. A small folded bath blanket is placed between the posterior bars and the skin.

Efficient postoperative immobilization of the grafted area is obtained. It should be noted that with the patient under sedation there is an increased likelihood of pressure sores. Inspection and cleansing of the skin is necessary once a day. We have encountered no significant skin necrosis in recent years.

After the operation, the brace will be desirably loose. In a day or two it should be lengthened, the back a little faster than the front to encourage flexion of the thoracic spine. The pressure pad is advanced. The deformity will diminish considerably and the brace will be comfortably snug. The apparatus is now lengthened only to take up slack. Symmetrical distraction should be used at all times. With each change the patient is instructed

to raise his chin and occiput from the brace. If he cannot do this, the correction has been too rapid.

The pressure pad should be tightened as the spine is straightened. It should be loose when the patient lies on the side opposite to it. The curve is corrected by alternating the forces of distraction and anteromedial pressure on the posterior prominence of the convexity. An efficient derotational force, as well as a medial thrust, is obtained from the pressure pad. The pad is advanced only when it becomes loose from correction of the curve or from stretching of the strap. It may be shifted slightly from day to day to avoid localized injury of the skin. The corrective force is largely an active one.

If the operation is performed in two stages, the brace should be removed in the operating room just before the second procedure. If the extension bars have been elongated to almost the limit, they should be replaced with longer ones to maintain the same length but provide for further extension. By having the parts ready, the work may be completed and the brace returned by the time the operation has been finished.

Additional correction of the curve will be obtained easily after the second stage. Taking up slack should be continued for about four weeks after the completion of this operation. The maximum correction has usually been obtained by then. After this the brace should be elongated only as the child grows. It must be kept comfortably tight at all times. Following the second operation, inspection and care of pressure areas are again important. After ten weeks the skin will have become tough and the pelvic girdle and the pressure pad should no longer be loosened. It is then wise to leave the brace undisturbed between monthly visits to the orthopaedist.

When the patient is permitted to walk, it is best to stop lengthening the brace even if the child has grown. Some vertical compression stress on the fusion area is desirable at this stage to toughen the graft.

A girl of fourteen years is kept recumbent for five months after the last operation. Younger children may walk after somewhat less time. There will be a danger of loss of correction and pseudarthrosis if walking is permitted too early.

Partial recurrence of deformity in the brace about ten weeks following the fusion is probably caused either by growth of the patient with failure to elongate the brace and advance the pressure pad or loss of corrective force due to diminution of subcutaneous fat, stretching of straps, or unauthorized loosening of the girdle.

Apparent increase in deformity may be due to a variation in the rotation of the spine with relation to the roentgenogram. Rotation may add some of the curve of the thoracic kyphosis to the corrected scoliosis.

After the removal of the brace, the usual cause for an increase in the curve is pseudarthrosis. The defect may be localized clinically by tenderness and roentgenographically in an oblique view with the graft in profile. After five months, side bending films may be used to demonstrate a point of motion. Pseudarthrosis should be identified promptly and repaired before the patient is permitted to walk. If a pseudarthrosis heals with the loss of considerable correction, an osteotomy should be done to regain most of the loss.

The general condition of the patient remains good during his convalescence. The physical therapist teaches deep breathing and abdominal retraction as well as foot exercises. Braces may be worn in bed to prevent equinus deformities, particularly in the patient with paralytic scoliosis.

When the patient first gets up, he should not attempt to sit. He may stand and later walk. When he returns to school, the pelvic girdle should be cut higher in each groin to permit sitting. The brace should be worn constantly for six weeks or more after the patient is permitted to walk. It is first discontinued at night and then for increasing periods during the day. Later, it should be replaced by a corset for abdominal support. Additional rest will be necessary for several months. Formal rehabilitation is unnecessary since the patient has been kept in good condition during the entire postoperative period.

RESULTS

The end results in eighty-seven patients with scoliosis operated upon by the senior authors and their associates over a twelve-year-period were subjected to a critical review. The patients who were treated conservatively with the Milwaukee brace (Fig. 1-A) are not included since it would be impractical to base an end-result study of these patients on our clinical impressions only. The distribution of age and sex is shown in Chart I. The follow-up time varied from one to twelve years with an average follow-up of 4.2 years. All patients were observed more than one year from the time of operation. The average age at the time of fusion was 12.4 years. Excluding four patients over eighteen, the average age was 10.3 years.

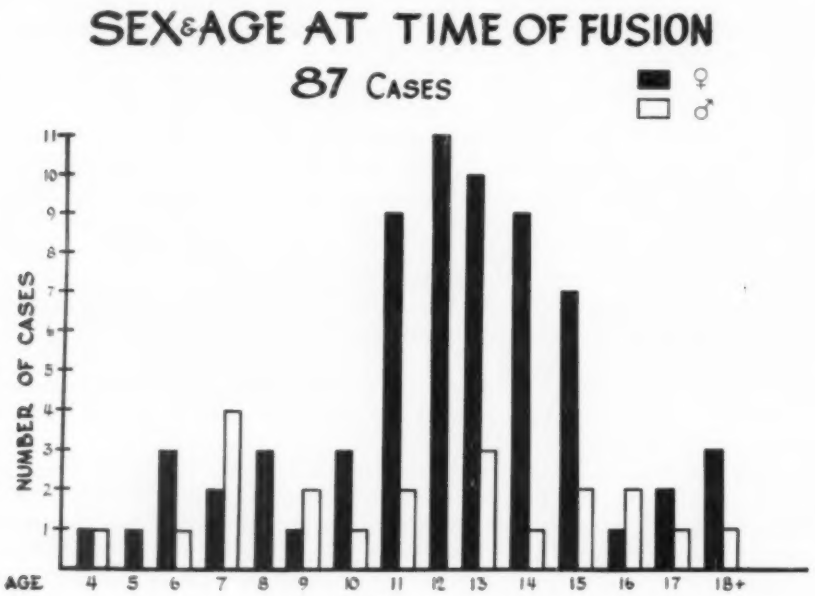

CHART I

The end results are given on consecutive cases. There were no deaths and no neurologic complications. In each case, the follow-up roentgenograms showed that the primary curve was improved, and that the appearance of the patient was considerably better following the treatment, with three exceptions. In one of these patients there was a serious postoperative infection in the caudad half of the grafted area and in all three, there were pseudarthroses which were not repaired. The major curve became greater than it was before the operation. In one, the cephalad portion of the curve remained fused and the posture in clothing was improved. In the other two, the appearance was slightly worse, but probably better than it would have been without the operation. These cases are listed as failures and are recorded in the tables as pseudarthroses. They are included in the end-result studies which would look considerably better without them.

In the evolution of the treatment of scoliosis, our work was so timed that we have had the benefit of the experience of such masters as Hibbs, Ferguson, Risser, Cobb, and others. In most instances, we have been satisfied with the fusion areas selected (Figs. 2-E, 3-D, and 4-D). In the few cases of growing children treated early in our series with inadequate length of the fusion area, one or more segments usually became added to the primary curves. In five patients, additional segments were fused at a later date. Reversal

TABLE I

CORRECTION OBTAINED FOLLOWING SURGERY

		Average Maximum Correction		Average Loss of Correction		Average Net Correction	
		(*Degrees*)	(*Per cent*)	(*Degrees*)	(*Per cent*)	(*Degrees*)	(*Per cent*)
Paralytic cases	33	35.0	57.4	12.9	37.0	22.0	36.1
Idiopathic cases	37	28.0	46.0	13.7	49.0	14.1	23.2
Miscellaneous cases	17	21.0	36.6	9.9	46.6	11.3	19.5
Total cases	87	29.3	48.8	12.6	43.0	16.6	27.6

TABLE II

INCIDENCE OF THIRTY-FOUR PSEUDARTHROSES

		Sex	Type of Scoliosis			Facets	
	Male	Female	Paralytic	Idiopathic	Miscellaneous	Fused	Not Fused
Total cases	21	66	33	37	17	26	61
Total pseudarthroses	9 (42.8%)	25 (37.8%)	11 (33.3%)	18 (48.6%)	5 (29.4%)	7 (26.9%)	27 (44.2%)
Pseudarthroses repaired	4	13	6	8	3	4	13
Pseudarthroses not repaired	5	12	5	10	2	3	14

of the list, elevation of a shoulder, or other evidence of too long a fused segment was not observed. A discussion of these complications has been published by one of us [15].

Table I is a record of improvement according to etiology. The total average net correction of 16.6 degrees or 27.6 per cent is of the greatest practical significance. Most provocative of thought in the second double column is the loss of improvement, expressed in both degrees and percentage, following an initial gain. There are three significant reasons for this unfortunate regression.

1. Inadequate immobilization from inefficient use of the brace allowed an early loss in specific instances. We obtained good correction but lost some of it because the parents loosened the braces, or even removed them. Our present rule forbidding any loosening after the tenth week has improved these figures.

2. Some operations were inadequate by our present standards because the exposure was not wide enough, the soft parts were not thoroughly removed, or the facets were not fused.

3. Homogenous bone is less salutary than autogenous bone in providing a solid fusion. Re-operations at intervals of from two weeks to a year have shown that such bone is more slowly accepted. When used in large quantities, it is replaced centrally by fibrous tissue rather than by new bone. An excess of homogenous bone predisposes to slow fusion and pseudarthrosis.

A shocking number of pseudarthroses have been reported by Gucker, James, Moe, and Ponseti and associates as well as by others. Our series shows a similar incidence. Of thirty-four failures of fusion, 39 per cent of the total, seventeen were repaired. Three poor results have been discussed. Fourteen patients maintained some correction without re-fusion. In one patient who was closely followed, pseudarthrosis (a questionable fatigue fracture) appeared suddenly twenty-seven months after surgery, with a loss of 19 degrees correction.

The results are classified in Table II with regard to sex, etiology, and whether or not the facets were fused. The incidence of pseudarthrosis does not show significant variation with regard to sex, 42.8 per cent in males and 37.8 per cent in females. There were more failures of fusion in patients with idiopathic curves (48.6 per cent) than in those with

TABLE III

PSEUDARTHROSIS BY AGE

Age (*Years*)	Pseudarthrosis Repaired	Pseudarthrosis Not Repaired	Total Pseudarthrosis
5			
6			
7		1	1
8			
9	1		1
10	2		2
11	1	1	2
12		3	3
13	5	6	11
14	1	2	3
15	1	2	3
16	1	1	2
17	1	1	2
Over 18	4		4
Total	17	17	34

paralytic curves (33.3 per cent) and least in those with congenital curves (29.4 per cent). The earlier cases without facet fusion were significantly worse (44.2 per cent) with regard to the occurrence of pseudarthrosis than the later ones (26.9 per cent) that included destruction of the posterior articulations (Figs. 3-E and 4-E).

Other factors were exceedingly variable. It should be noted that a few of the best results were early ones when ambulation was permitted at two months (Figs. 2-C and 2-F). Later, patients who were kept in bed for six months without facet fusion had a higher percentage of pseudarthrosis than those in whom fusion was recently done with destruction of the posterior articulations but who had bed-rest for only four to five months (Table II). The incidence of pseudarthrosis is broken down by ages in Table III. The results are not significant.

The identification of a pseudarthrosis is sometimes very difficult, and the criteria are variable. Clinically, localized tenderness and loss of correction are significant. In a roentgenogram made with the patient standing, loss of correction, and in the oblique view, a characteristic zone of radiolucency are diagnostic. If these criteria alone had been used, the percentage would have appeared much lower than the actual incidence. We have considered that all patients had pseudarthrosis if a rapid loss of correction of more than 15 degrees occurred after the patient began to walk. The curve may have become stabilized in the new position and the pseudarthrosis fused solidly. In a few of these patients with spontaneous healing, an osteotomy of the graft was performed and the curve again corrected. In some patients a persistent pseudarthrosis was found and re-fused with autogenous bone. We are convinced that it is unwise to attempt a pseudarthrosis repair with homogenous bone. In no case was there failure of union on the second attempt.

COMMENT

In the treatment of scoliosis, it is important to think of the posture, health, and function of the patient and not merely of straightening the shadows seen in the roentgenogram. One is constantly faced with the problem of when to operate. In some cases, the Milwaukee brace has been used to postpone surgery. It is unwise to fuse unnecessarily when the patient is very young. It is also unwise to neglect the patient so long that he develops disastrous, irreversible changes. It is our conviction that there is no justification for with-

holding operation from a growing child because of fear of complications and changes that might occur with further growth.

In the past, the difficulties associated with correction and fixation deterred most men from attempting the operative treatment except in the most severe cases. The Milwaukee brace relieves the surgeon of the chore of making a huge operative cast. It is more comfortable for the patient than the cast and lessens some of his objections to the operation.

With the method of correction and fixation simplified, it would seem logical to operate earlier on the progressive curves and thus diminish the duration of treatment and the ultimate deformity for a greater number of children.

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Making the Milwaukee Brace*

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PREPARATION OF THE MODEL

The most important single requirement for satisfactory use of the Milwaukee brace is an intelligent, skillful, cooperative orthotist. If such an expert is not available, the method should not be attempted. If such a man can be called on to make, fit, and modify the brace as necessary, the technique may be used with satisfaction in the most difficult cases [1].

The orthotist is supplied with a negative plaster model which usually includes only the torso from the upper part of the thigh to the nipple line (Fig. 1, *X*). It is occasionally more satisfactory for the bracemaker to have the plaster include the chin and occiput (Fig. 1, *Y*). Then the patient need not report for a fitting until the brace is completed.

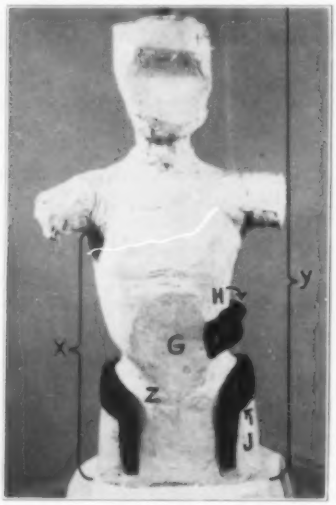


FIG. 1

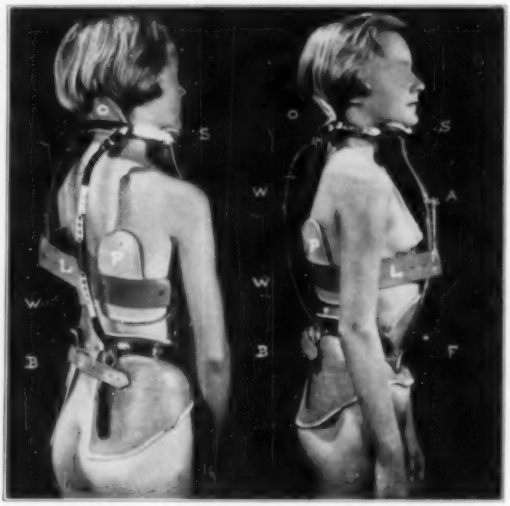


FIG. 2

Fig. 1: Plaster positive prepared for molding on the leather of the pelvic girdle. The average model extends from below the buttocks only to the armpits, *X*. If the patient cannot come in for a fitting it is well to extend the plaster to include the chin and occiput and the shoulders, *Y*. The abdomen has been skived flat, *G*. The plaster has been cut away to accentuate the iliac crests, *Z*. The anterior superior spines have been spotted with felt, and other layers of felt are continued over the iliac crests, *J*. The rib margin on the side opposite the convexity has been built out, *H*, to make the rib cage symmetrical.

Fig. 2: This Milwaukee brace had been worn for one year. The pelvic girdle was small, and was replaced at the time this photograph was made. See text for details of construction. (Reprinted by permission from "The Treatment of Scoliosis" by W. P. Blount. *Sixième Congrès International de Chirurgie orthopédique*, p. 224. Bruxelles, Imprimerie Lielens, 1955).

The patient is suspended with a head halter until there is a comfortable degree of correction. The torso is steadied by a metal frame while the cast is made. The pelvic portion of the cast is applied first and molded sharply over the crests of the ilia to accentuate the waistline. It is well to pull a twisted strand of plaster bandage forward and downward above the iliac crests on each side. Then the cast is molded from back to front so as to push the excess plaster forward. The protrusion of the abdomen will be corrected by cutting away the plaster positive at a later stage.

If the poliomyelitic patient has difficulty breathing, the lower half of the cast can be split posteriorly to permit abdominal respiration and lessen the patient's apprehension before the upper portion of the model is completed. When the cast is set, a vertical cut is made along a thin wire cable. This cable is suspended longitudinally next to the skin before the cast is started.

* Much of this paper appeared in *Braces Today*, April and May, 1956.

Before the cast is removed, the vertical distance from the chin to a mark on the front of the cast at about the level of the xiphoid process and the diameter of the neck should be measured. When the cast is removed, the point marking the xiphoid process is preserved by piercing the plaster with a knife. The shell is then restored with several turns of plaster. The name of the patient and the location of the pressure pad are indicated on the model and it is ready for the brace shop.

The bracemaker pours a plaster positive. An iron rod serving as a central core protrudes six to eight inches (15 to 20 centimeters) above the top of the plaster for ease in handling. The shell of plaster bandages is stripped from the model within one or two hours and the model is skived as soon as convenient. Reshaping the model is most important for obtaining correction and as well as for the comfort of the patient and the avoidance of pressure sores. The abdomen should be skived flat in a plane from the symphysis pubis to the costal margin (Fig. 1, *G*). The torso must then be made to assume the corrected position of the patient with exaggerated bony landmarks. For example, with a right thoracic primary curve, the plaster is cut away sharply above the right iliac crest to accentuate it (Fig. 1, *Z*). Pressure is then distributed along the top instead of along the lateral side of the ilium. The entire lower half of the torso is smoothed out to prepare for molding the leather.

The left iliac crest is already prominent. Above the constricted waistline on the left, the model is filled out with as much as two inches (5 centimeters) of felt padding to balance the other side (Fig. 1, *H*). This padding should extend upward four to five inches (10 to 13 centimeters) so that the remodeled form has the shape of the torso after correction of the scoliosis. It is then easy to displace the rib cage to the side opposite the convexity.

The anterior superior spines are spotted with round pieces of felt one-quarter of an inch (0.6 centimeter) thick. In addition, both iliac crests including the anterior superior and inferior spines are padded with the same type of felt (Fig. 1, *J*). The lower portion of the model is now essentially symmetrical.

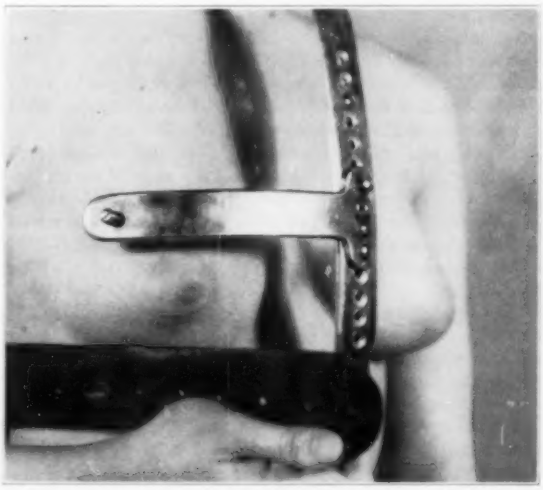


FIG. 3

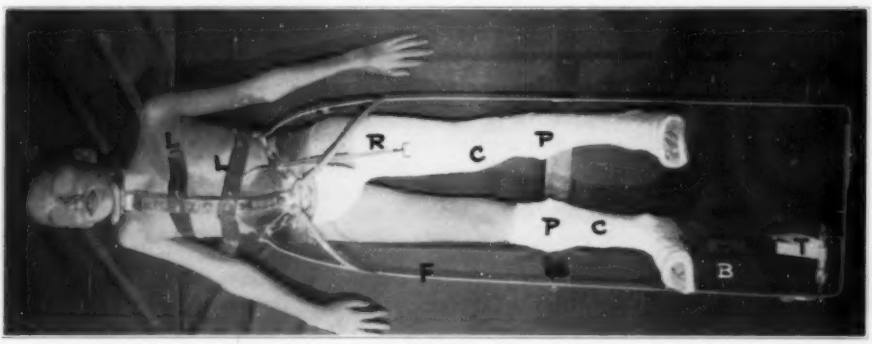


FIG. 4

Fig. 3: The anterior attachment of the pressure-pad strap has been shifted to the end of an outrigger from which it has just been removed. The outrigger serves to keep pressure off a developing breast. It may be used also to change the direction of the force exerted. Occasionally such an outrigger is notched at the end and used to attach wire or rubber band traction posteriorly on the spine, particularly in patients with thoracic lordosis, extreme rotation, or both.

Fig. 4: An accessory traction frame is used in cases of pelvic obliquity combined with scoliosis. *L* denotes the straps for the pressure pads; *F*, the metal frame screwed to metal parts of the pelvic girdle; *C*, the casts incorporating the transfixion pins, *P*. The long cast is drawn upward by two heavy rubber bands, *R*, one anteriorly and one posteriorly. Ratchet traction, *T*, is made on the short cast on the side of the high hip. The tension is controlled by the spring balance, *B*.

MAKING THE BRACE

Vegetable tanned cowhide is well soaked in water before it is stretched over the model. It must extend from the gluteal folds and pubis to the rib margins. It will be found advantageous to center the leather and then hold it temporarily with two tacks in front. The leather, molded very closely and with one end tacked in back, is then stretched tightly and the other end similarly tacked. This foundation is left long until accurately fitted. When the patient is able to walk, the leather must be cut away in the groins to permit flexion of the hips in sitting. It is trimmed so as to curve upward in front to support the abdomen, but lower on the sides to avoid pressure on the ribs.

The leather girdle is re-inforced by 16-gauge (one-sixteenth of an inch or 0.16 centimeter thick) or 18-gauge (three sixty-fourths of an inch, 0.117 centimeter thick) Monel metal strips one and one-quarter inches (3.2 centimeters) in width. These strips are forged cold to fit the contours of the areas to be covered, and should be rounded to form the shape of half of a tube above the iliac crests. From the fork (Fig. 2, *F*) in front of the pubis, they extend upward on either side, then backward to fit the constricted waistline groove where the model was skived. The strips continue back almost to the posterior superior spines where they make a right angle turn and continue to the bottom of the leather girdle.

The headpiece consists of several parts. There are two horseshoe-like forged cold rolled steel strips one-eighth inch by five-eighths inch (0.3 by 1.5 centimeters). They meet and overlap for two inches (5 centimeters) on either side of the neck. Here they are slotted for adjustability and are held together by two screws on each side. The front half carries the chin support (Fig. 2, *S*), which is made of aluminum alloy, type 2024-T3. It is a kidney-shaped platform which is curled up at the lateral edges but not cupped at the front of the chin. It should extend well back under the mandible on each side. The occiput plate (Fig. 2, *O*) is notched to accommodate the occipital protuberance, and is riveted to the posterior half of the headpiece.

The chin and occiput pieces are padded with air-foam rubber one-half inch (1.27 centimeters) thick and covered with horsehide on the inside and natural kip on the outside. In most cases it is well to extend a padded tongue forward from the occipital piece to the angle of the jaw on the side opposite the convexity of the scoliosis. The pads are attached to the metal parts outside of the calfskin. At the center, the chinpiece is attached to the curved steel frame by rivets. From the center of this frame a single upright aluminum bar (Fig. 2, *A*) extends downward. It is made from one-quarter by one and one-half inch (0.6 by 3.8 centimeters) aluminum alloy, type 2024-T3, to permit penetration by the roentgen rays. For extensibility, it is made in two halves with a long overlap. The lower end extends low enough to support the abdomen, and is fastened by an inverted fork (Fig. 2, *F*) to the front of the pelvic frame by strong rivets.

The posterior halfring is supported by two upright bars (Fig. 2, *W*) of cold rolled steel measuring three-sixteenths by three-quarters of an inch (0.5 by 1.9 centimeters). These bars are welded to the back of the posterior horseshoe in the sagittal plane and angulate somewhat posteriorly to clear the shoulder muscles. In the first one and one-half inches (3.8 centimeters) they are twisted so that they lie in the frontal plane. These two bars are also made in two parts with an overlap for adjustability. The lower ends are fastened to the pelvic frame posteriorly by two large rivets on each side. All three bars must be bent to fit the contours of the corrected torso. They must form a cage which is amply large to avoid pressure.

The lateral pressure pad (Fig. 2, *P*) is made like the chin support and mounted on a seven-ounce yellow latigo leather strap (Fig. 2, *L*). The pressure pad is easily shifted forward or back, up or down. The strap is secured to the front bar and to the farther of the posterior bars by truss studs. A horizontal T-shaped outrigger may be interposed and attached to the frontpiece to prevent pressure on a breast (Fig. 3).

In patients with thoracic curves, one pressure pad at the convexity may be enough. In those with low curves, a pressure pad at the site of the convexity should be combined with a narrow sling at the opposite axilla to give counterpressure against the upper ribs. Patients with double curves require a high pressure pad that may be secured by a strap over the shoulder and a second pad below the costal margin on the opposite side. In some cases, after the primary curve is well corrected, one may use an additional sling on the opposite side, either low or high, to stabilize the torso and prevent excessive movement.

If the brace is being made from measurements, it is well for the bracemaker to fit it to the patient before it is complete, standing, sitting, and lying down. The relationship of the occipital pad to the protuberance should be observed. The pelvic girdle must be snugly fitted in the waist with plenty of room over the iliac crests. It must be amply high to support the lower abdomen. The chinpiece must not prevent the patient from protruding the chin forward and from widely opening the mouth.

The brace is then completely dismantled and all metal parts polished. The pelvic girdle is lined with light-weight horsehide. This leather is turned back over the edges of the cowhide and stitched except in the groin where the lining is left protruding one-quarter of an inch (0.6 centimeter) to allow stretching.

ACCESSORIES

A T-shaped outrigger (Fig. 3) is supplied to prevent pressure on a breast or change the direction of force of a pressure pad. The leather strap (Fig. 2, *L*) is fastened to a truss stud at the tip of the long arm. Three or four screws hold the outrigger to the upright arm.

(Continued on page 624)

A Critical Analysis of Methods of Fusion for Scoliosis

An Evaluation in Two Hundred and Sixty-Six Patients *

BY JOHN H. MOE, M.D., MINNEAPOLIS, MINNESOTA

INTRODUCTION

The evolution of spine fusion has been well described by Howorth. The following is a brief review of the development of the Hibbs fusion.

The first spine-fusion procedure was reported by Hibbs in 1911 [5]. He reported three patients with Pott's disease treated by spine fusion and suggested that the procedure might well be used in scoliosis.

Hibbs [6], in 1924, reported a study of fifty-nine patients with scoliosis treated by fusion, in some of whom there was correction and in some there was not. He stated that the first fusion for scoliosis was done in 1914.

The technique described by Hibbs [5] in 1911 was quite different from that described in 1924. In 1911 the procedure consisted in partially shearing off the base of the spinous processes and breaking them down to bridge the interlaminar spaces. In 1924 he described the technique which has remained the classic Hibbs method of spine fusion.

Since the term *Hibbs method of fusion* has been loosely applied to a variety of techniques outlined in operative reports, it might well be fitting to review this technique as described by Hibbs in 1924.

"An incision is made through the skin and subcutaneous tissue, from above downward, exposing the tips of the spinous processes of the vertebrae to be fused. The periosteum over the tips of these processes is split longitudinally, and, with a periosteal elevator, pushed to either side, leaving them bare. The periosteum and interspinous ligaments in turn are still farther split and pushed forward a short distance from each spinous process, as two lateral halves, gauze packs being inserted to prevent oozing. The dissection is carried farther and farther forward upon each vertebra in turn, until the spinous processes, the posterior surfaces of the laminae, and the base of the transverse processes are bared, thereby exposing the ligamentum subflavum attached to the margins of the laminae and the articulations of the lateral processes.

"The ligament is removed from the laminae with a curette, and the articulation of the lateral processes is destroyed in order to establish bone contact at this point. With a bone gouge, a substantial piece of bone is elevated from the adjacent edges of each lamina, of half its thickness and of half its width. The free end of the piece from above is turned down to make contact with the lamina below, and the free end of the piece from the lamina below is turned up to make contact with the lamina above. In transposing these pieces of bone from the laminae, it is better to avoid severing their continuity.

"Each spinous process is then partially divided with bone forceps and broken down, forcing the tip to come into contact with the bare bone of the vertebra below. The spinous process of the last vertebra below should be turned up to bring about contact with the next above. As the spinous processes of the lumbar region are wide, it is sometimes practicable to split them, turning one half up and the other half down. Thus is established contact of abundant cancellous bone at the articulations of the lateral processes, laminae, and spinous processes. The periosteum and ligament, which together have been pushed to either side and lie practically as an unbroken sheet, are brought together in the middle with interrupted sutures of ten-day chromic catgut."

It must be conceded that any method of spine fusion in which fragments or leaves of bone are elevated from the laminae and spinous processes and are turned up and down in a transposed manner is a modification of the Hibbs technique. However, as is so clearly pointed out in Hibbs' own text, the subperiosteal exposure is meticulous and wide, and the elevation of the bone fragments is done in a specific way and in a specific region. One must question the amount of bone-to-bone contact obtained by the Hibbs technique of curettement of the inferior margins of the vertebral articulations.

In the classification of the methods of fusion to be described, it should be emphasized that no inference should be drawn that any new method of fusion is being described.

* Read at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 26, 1957.

TABLE I

Time Since Fusion	Curves Due to Idiopathic Scoliosis	Curves Due to Paralytic Scoliosis	Total
14 to 18 mos.	13	11	24
18 to 24 mos.	12	15	27
24 to 36 mos.	36	43	79
Over 3 yrs.	68	65	133
Total	129	134	263 *

* Not included are one patient with idiopathic and two with paralytic scoliosis still under treatment for pseudarthroses.

The author's early type of fusion differed from the other methods in that exposure was mostly not subperiosteal, nor was it very wide. The Cobb method was a Hibbs subperiosteal exposure, and a slightly modified Hibbs fusion, but did not specifically include curettage of the articular facets. Both the early method and the Cobb method differed from the Hibbs technique in that bone was added throughout the fusion area. The technique of articular-facet fusion is also a Hibbs subperiosteal exposure; the joint-fusion

TABLE II

Idiopathic Scoliosis: Degree of Curvature Maximal Angle (*Degrees*)	No. of Patients	Paralytic Scoliosis: Degree of Curvature Maximal Angle (*Degrees*)	No. of Patients
35 to 50	14	35 to 50	14
50 to 65	42	50 to 65	41
65 to 80	38	65 to 80	38
80 to 95	25	80 to 95	22
95 to 125	8	95 to 125	16
Over 125	3	Over 125	5
Total	130		136

technique is a combination of methods described by Howorth and McBride. The method of decortication of the spinous processes and laminae and bridging of the interlaminar spaces is similar to that described by Howorth. The stressing of the bridging of the transverse processes laterally has been called to the author's attention by Blount. It is perhaps regrettable that at no time in this series was the classic technique of Hibbs followed.

MATERIAL AND METHODS

The data presented in this follow-up study of scoliosis have been obtained by the author's personal evaluation of patients treated privately and at the Gillette State Hospital

TABLE III

DIAGNOSIS OF PATIENTS WITH SCOLIOSIS TREATED SINCE 1947

Idiopathic scoliosis *	151
Paralytic scoliosis	179
Congenital scoliosis	48
Thoracogenic scoliosis	1
Neurogenic scoliosis	2

* In this group are two patients with *café-au-lait* skin markings.

for Crippled Children in St. Paul, Minnesota. Patients treated between the years 1947 and 1956 are included (Table I). A majority were followed for from two to eight years postoperatively. Relatively few patients are included who were followed for only fourteen to eighteen months. In these it was the author's opinion that the fusion was solid beyond question and that the spine was remaining stable after a period of five months or longer without external support. (In the months following completion of this survey, these patients have been carefully re-examined. No further loss of correction has been noted.)

The study is based upon an analysis of 266 patients having curvatures classified as idiopathic and paralytic scoliosis (Table II). The total number of patients treated since 1947 is 381. Only one patient in the entire group has been lost to follow-up analysis.

This study does not include all patients seen with scoliosis. Cobb expressed the opinion in 1948 that only 5 per cent of patients with idiopathic and 50 per cent of those with paralytic scoliosis need correction and fusion of the spine. In the patients seen on the scoliosis service of the Gillette Hospital, probably more than 75 per cent of the idiopathic curvatures were cosmetically deforming, with a curve of 50 degrees or more. Correction was felt desirable and necessary in a high percentage of patients seen. Spines were eventually fused in nearly all of the patients with paralytic scoliosis referred to the scoliosis service, because of a severe or progressive curve.

There are 115 patients still under treatment who have been followed for too short a period of time to be included in this survey. Of the entire group treated, 151 cases were classified as idiopathic scoliosis and 179 as paralytic scoliosis secondary to poliomyelitis (Table III).

For purposes of analysis and comparison, it was found impractical to evaluate two curves in one patient. In idiopathic scoliosis it is nearly always possible to demonstrate that one of the curves is greater and shows more structural deformity than the other. Therefore, in analyzing idiopathic curvature, such a single curve was selected for purposes of comparative evaluation. In patients with paralytic scoliosis, two curves of equal angle, magnitude, and structural deformity were not infrequently found. These were eliminated as a separate group when the percentage of correction and the cosmetic result were evaluated. In determining the percentage and number of pseudarthroses no such separation was, of course, necessary. In attempting to classify results of treatment, the author has correlated cosmetic appearance with the correction of the curvature as shown by roentgenogram.

As one observes and studies numbers of patients with scoliosis, it becomes obvious that roentgenographic evidence of corrected curvature is only one criterion by which the end result should be judged. As Schmidt has pointed out, a fused spinal column is easier to maintain in balance than a flexible one. The regaining of compensation and the improved appearance resulting from it can sometimes be obtained with little or even no roentgenographic evidence of correction of the curvature. The author has tried to evaluate the cosmetic appearance of the patients fairly, using not only his own repeated observations on each patient, but also the patient's opinion and that of the parents. An excellent and good result is apparent to everyone; a fair result indicates improvement in appearance and reasonable satisfaction; a poor result indicates general dissatisfaction on the part of all concerned (Figs. 1-A through 1-E).

The turnbuckle cast of Risser, as modified by Cobb, was used between the years 1948 to 1953. During this period, the Milwaukee brace of Blount and Schmidt was also used in a number of patients. Beginning in 1953 the Risser localizer cast was tried. With increasing experience in its application, this type of cast was found to be equally as efficient as the turnbuckle cast and was far better tolerated by the patient. Since 1954, the localizer cast has been used almost routinely. During the past year most of the difficulties previously encountered in obtaining a well fitting Milwaukee brace have been overcome. This brace, when well fitted, provided excellent correction and was well tolerated by the patient.

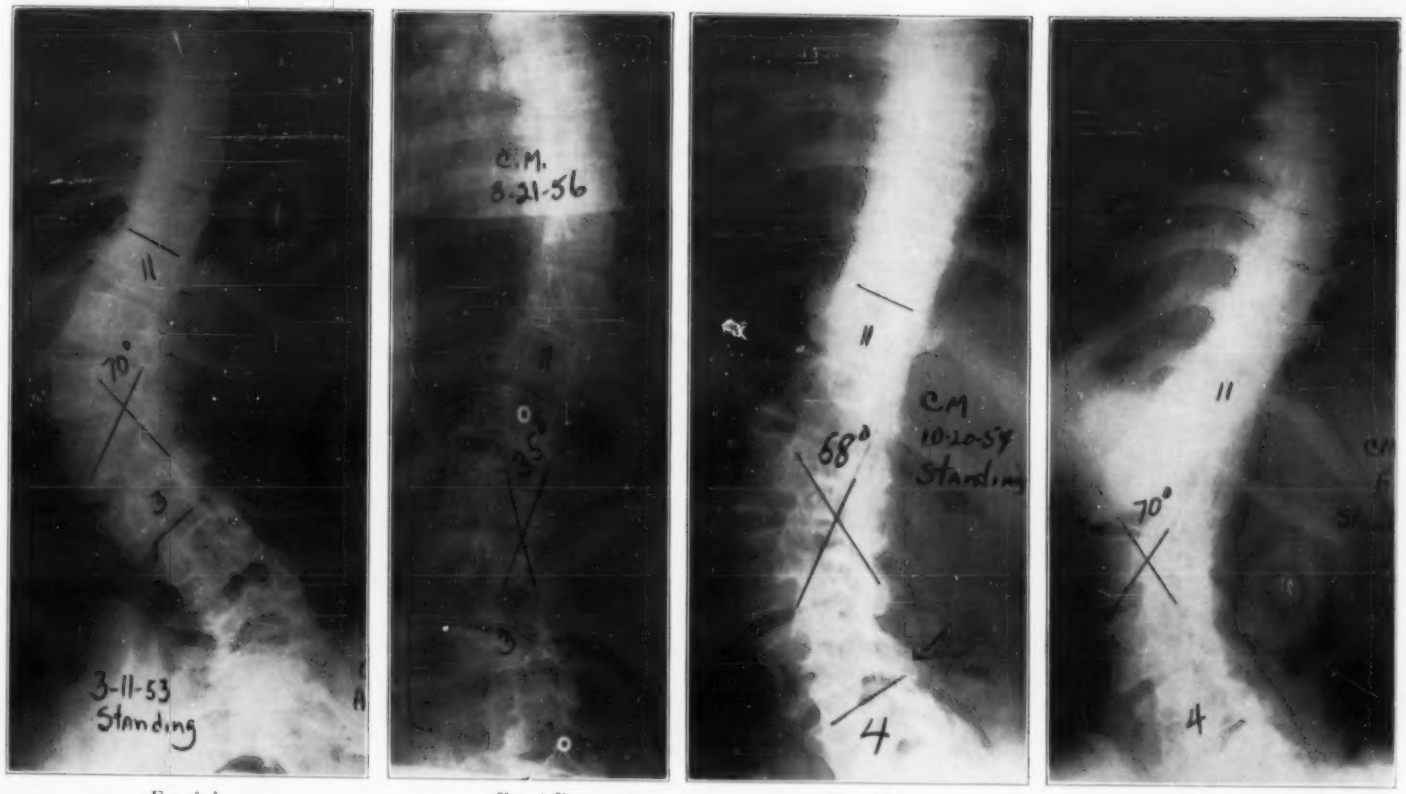


FIG. 1-A FIG. 1-B FIG. 1-C FIG. 1-D

Figs. 1-A through 1-E: Roentgenograms and photographs showing poor result of fusion in a patient with scoliosis. C. M., aged twelve years, eleven months, had idiopathic scoliosis and congenital defects of the heart septa. The left curve, from the eleventh thoracic to the third lumbar vertebra, was 70 degrees. The scoliotic curve was lessened to 35 degrees after spine fusion on April 22, 1953. Pseudarthroses which were untreated caused complete loss of correction and the cosmetic appearance was much worse after treatment than before.

IDIOPATHIC SCOLIOSIS

There is general agreement that the clinical entity known as idiopathic scoliosis does exist and that its clinical course and pattern will usually differ from that of scoliosis following poliomyelitis. The borderlines of differentiation are, however, often indistinct. For purposes of this study, no curvature was termed idiopathic when there was a definite history of poliomyelitis, even in the absence of demonstrable muscle weakness. No curvatures with vertebral anomalies, whether congenital or associated with neurofibromatosis, were included. However, the presence of *café-au-lait* marking on the skin in the presence of a typical idiopathic-curve pattern was not felt to be of significance. Likewise, the presence of congenital anomalies elsewhere in the body such as ectopic liver, congenital heart lesions, congenital hip dislocation, or congenital anomalies in the extremities was not felt to be significant if the curvature was typically idiopathic in pattern and appearance.

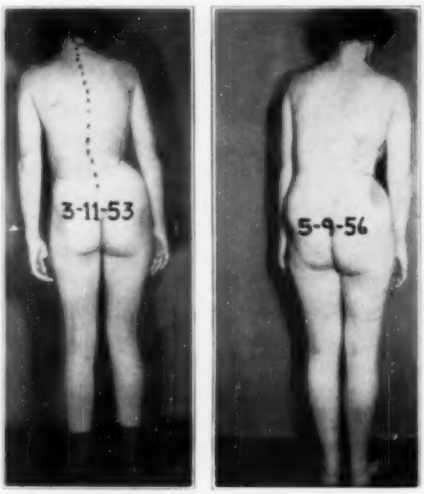


FIG. 1-E

There were 130 patients with scoliosis classified as idiopathic, ninety-eight of whom were treated at Gillette Hospital and thirty-two privately. There were 116 females (89 per cent) and fourteen males (11 per cent). The average age at the time of fusion was 13.8 years, the youngest being nine years, the oldest forty (Table IV).

The curve patterns were based on Ponseti and Friedman's and on James' classification with the exception that since there were no curves limited to the lumbar spine none were classified as primary lumbar scoliosis (Table V).

Evaluation of Correction

The percentage of correction gained was calculated by subtracting the final degree of curvature from the maximum curvature as shown in a roentgenogram made with the patient standing previous to correction. This difference was then divided by the degree of the original curvature.

A roentgenogram made with the patient either standing or sitting when he was last seen was used for the final evaluation (Table VI).

The average gain in this series was 40 per cent. Patients with solid fusion in whom no pseudarthroses developed gained an average of 43 per cent. Those patients with pseudarthroses gained on an average of 22 per cent while in those in whom pseudarthroses persisted there was only a 13 per cent average gain.

When the average percentage gain was correlated with the cosmetic evaluation (Table VII), it was found that 101 patients rated as having good cosmetic results showed an average gain of 45 per cent, twenty patients rated as having fair results gained 24 per cent and eight with poor results showed only a 5 per cent gain.

In this series, 78 per cent of the total number of patients were rated as having good cosmetic results. When solid fusions were present with no evidence of graft defect at any time, 86 per cent had good results. With pseudarthroses present in the graft, 53 per cent were considered as having good cosmetic results, and with the graft defects persisting, only 25 per cent were so classified.

TABLE IV

IDIOPATHIC SCOLIOSIS

Age at Time of Fusion (*Years*)	No. of Patients
9 to 11	7
11 to 13	25
13 to 15	44
15 to 17	37
17 to 19	8
19 to 21	6
Over 21	3

Loss of Correction During Treatment

The average loss of correction was 12 degrees in all patients with idiopathic scoliosis (Table VIII). Patients with solid fusion without defects averaged 10 degrees loss, while in those with pseudarthroses persisting, the average loss was 39 degrees.

Loss of correction in patients with fused spines can occur without evidence of pseudarthrosis but, except for a short area of fusion, which can produce a severe recurrence of deformity, the presence of one or more pseudarthroses accounted for nearly all major losses of correction. While the presence of a graft defect does not necessarily mean loss of correction if discovered, protected by adequate external support, and repaired, it is nevertheless evident from the foregoing data that the average percentage of gain in correction is markedly reduced by the development of defects in the graft. It is of interest to note that a small number of pseudarthroses persist without severe loss of correction.

Types of Fusion

The total number of patients analyzed with idiopathic scoliosis was 130. In this group, there were 165 separate spine-fusion operations performed. The total number of operations for repair of pseudarthrosis was twenty-two. The methods of performing spine fusion can be divided into three general types.

Early type: When the scoliosis service was initiated in 1948 at Gillette Hospital, a method of fusion then common in this hospital was used. In this analysis this is termed the *early method of fusion* (Table IX). While subject to some variation, there generally was soft-tissue stripping from spinous processes and laminae with a sharp osteotome. The interspinous ligaments were not removed and a good deal of tags of soft tissue remained. The exposure was not carried beyond the base of the transverse processes in the thoracic area and the joints were nowhere exposed and denuded of soft tissue or cartilage. Decortication of the exposed bone was not meticulous. Criss-crossing flaps of bone were turned down and bone in the form of struts, reed grafts, or crumbled bone was added to the prepared area.

TABLE V

CURVE PATTERNS IN 130 PATIENTS WITH IDIOPATHIC SCOLIOSIS

Pattern	No. of Cases	Per Cen
Right thoracic	54	42
Left thoracic	3	2
Right thoracolumbar	40	31
Left thoracolumbar	13	10
Right thoracic, left lumbar	2	1
Right thoracic, left thoracolumbar	13	10
Left thoracic, right thoracic	1	1
Left thoracic, right thoracolumbar	4	3

TABLE VI

AVERAGE PERCENTAGE GAIN IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

	No. of Patients	Average Percentage Gain
Patients with idiopathic scoliosis	129 *	40
Patients with solid fusion excluding those with pseudarthroses	99	43
Patients with pseudarthroses	30	22
Patients in whom pseudarthroses became solid	18	26
Patients with pseudarthroses persisting	12	13

* One patient with pseudarthrosis who is still under treatment is not included.

Cobb method: In 1952, following an opportunity of observing the technique of spine fusion of Cobb, the author revised his method of fusion in an attempt to follow Cobb's technique and to teach this method to his operating resident staff. The fusions done in this series during 1952 and 1953 were done more or less according to this method (Table X). It is conceded that the technique seldom emulated that so masterfully done by Cobb. The Cobb fusion consisted in meticulous subperiosteal removal of muscle and all soft tissue from the spinous processes, laminae, and transverse processes. Multiple flaps of bone, raised with Cobb gouges, were left attached; the free end of each flap was placed under a trap-door flap of bone raised from a portion of the laminae or transverse processes of the next adjacent vertebra. In this way, there was complete decortication of the exposed bone and the final bed was made up of these multiple interlocking flaps, incorporating the transverse processes as well as the laminae and spinous processes. Substantial amounts of bone were then added. The joints were not disturbed.

Articular-facet fusion: In 1953, following an opportunity of observing the Hibbs fusion technique of Risser, the author's technique was modified to include destruction and incorporation of bone into the articular facets (Table XI). It was felt that a flap of bone raised over the thoracic articular facets which did not actually enter the joint would afford a safe approach for the purpose of removing the articular surfaces and would create a cleft into which flaps of bone from the next caudad vertebra could be inserted, filling the

TABLE VII

AVERAGE PERCENTAGE GAIN CORRELATED WITH COSMETIC EVALUATION IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

Cosmetic Rating	No. of Patients	Average Percentage Gain
Total patients (129)		
Good	101	45
Fair	20	24
Poor	8	5
Patients with solid fusions excluding those with pseudarthroses (99)		
Good	85	44
Fair	13	25
Poor	1	10
Total patients with pseudarthroses (30)		
Good	16	37
Fair	7	17
Poor	7	1
Patients with persistent pseudarthroses (12)		
Good	3	40
Fair	4	18
Poor	5	1

TABLE VIII

LOSS OF CORRECTION DURING TREATMENT IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

	No. of Patients	Loss (*Degrees*)
Patients with idiopathic scoliosis	129	12
Patients with solid fusions excluding those with pseudarthroses	99	10
Patients in whom pseudarthroses became solid	18	19
Patients with pseudarthroses persisting	12	39

cut-out joint surface tightly. This, combined with the interlocking flaps of the Cobb technique, was used for a time. The Chandler or Risser technique of crushing the articular facets was used in the lumbar area. For a considerable time no additional bone was used (Figs. 2-A through 2-D). During the last two years the author has again revised this technique by inserting blocks of cancellous and cortical bone into the cut-out articular facets in both the thoracic and lumbar areas, recessing these blocks into the next caudad articular process, much as in the technique of McBride in his low-lumbar fusion. The blocks are cut from the transverse or spinous processes or from a segment of iliac bone (Figs. 3 and 4).

TABLE IX

EARLY-TYPE FUSIONS IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

Type of Bone Added	No. of Cases	No. of Pseudarthroses	Percentage of Pseudarthroses
Autogenous bone	27	15	56
Bone-bank bone	3	2	67
Autogenous bone plus bone-bank bone	4	2	50
Total	34	19	56

Comparison of the Cobb technique with that of articular-facet fusion indicates that, in idiopathic scoliosis, the use of autogenous bone results in approximately the same percentage of pseudarthrosis with either method (Table XII). Cobb indicated that fusion of the articular facets is relatively unimportant provided that a meticulous interlocking fusion is carried out. The statistical data here presented would tend to verify this opinion when a spine with an idiopathic curvature is fused.

A comparison of patients treated at Gillette Hospital, where a majority of the operations were performed by the resident staff, with those patients treated in the author's private practice, indicates that a more favorable result might be forthcoming when the fusions are performed by one individual.

PARALYTIC SCOLIOSIS

There were 136 patients analyzed with scoliosis due to poliomyelitis. There were

TABLE X

COBB-TYPE FUSIONS IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

Type of Bone Added	No. of Cases	No. of Pseudarthroses	Percentage of Pseudarthroses
Autogenous bone	28	1	4
Autogenous bone plus bone-bank bone	2	1	50
Total	30	2	7

FIG. 2-A

FIG. 2-B

Fig. 2-A: Drawing shows the Risser technique of articular-facet fusion in the lumbar spine in which curettement of the articular facet, cross-cutting with a gouge, and impaction are performed. (Reprinted by permission from "The Management of Paralytic Scoliosis" by J. H. Moe, *Southern Medical Journal*, **50**: 79, 1957.)

Fig. 2-B: Drawing shows Chandler technique of articular-facet fusion in the lumbar spine in which curettement and cutting out of the side wall of the articular facet, and impaction of the fragments into the articular facet are performed. (Reprinted by permission from "The Management of Paralytic Scoliosis" by J. H. Moe, *Southern Medical Journal*, **50**: 79, 1957.)

FIG. 2-C

FIG. 2-D

Drawings show the author's early method of articular-facet fusion. (Reprinted by permission from "The Management of Paralytic Scoliosis" by J. H. Moe, *Southern Medical Journal*, **50**: 80, 1957.)

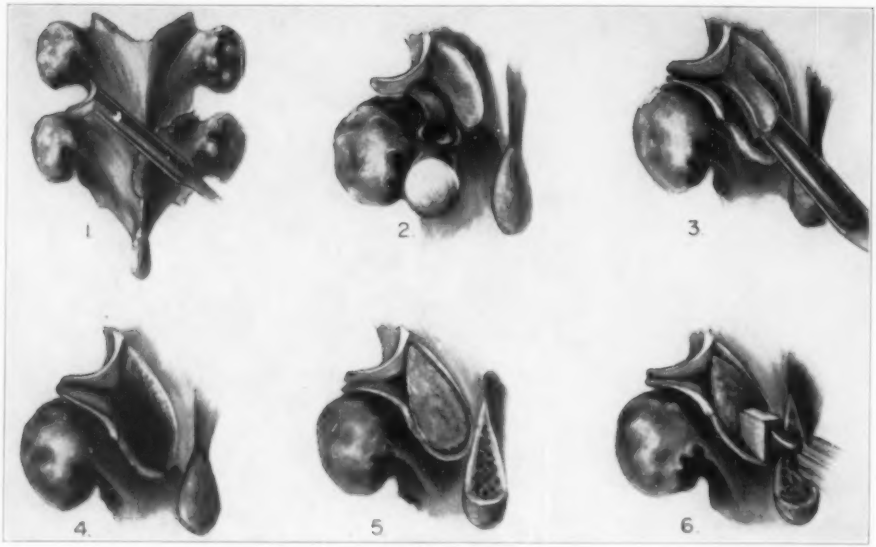


FIG. 3

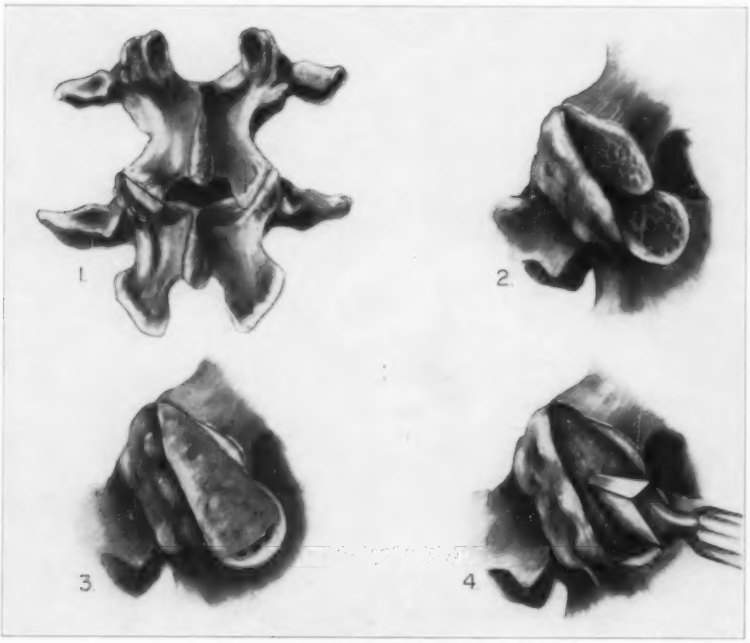


FIG. 4

Figs. 3 and 4: Drawings show the author's present method of articular-facet fusion.

eighty-one females (60 per cent) and fifty-five males (40 per cent). The youngest patient at time of fusion was three years of age, the oldest, twenty years. Sixty-five per cent of the curves were right thoracolumbar or right thoracic (Table XIII).

TABLE XI

ARTICULAR-FACET FUSIONS IN PATIENTS WITH IDIOPATHIC SCOLIOSIS

Type of Bone Added	No. of Cases	No. of Pseudarthroses	Percentage of Pseudarthroses
No bone added	21	6	29
Autogenous bone	29	2	7
Bone-bank bone	15	2	13
Autogenous bone plus bone-bank bone	1		
Total	66	10	15

Evaluation of Correction

The average gain in patients with paralytic scoliosis was 44 per cent (Table XIV). Those patients with fusions becoming solid without evidence of pseudarthroses at any time gained 47 per cent. Patients with graft defects gained 39 per cent, while in those with defects persisting in the graft, the average gain was 29 per cent.

Nineteen patients had double curves of equal magnitude and were omitted in evaluating the percentage of gain and the cosmetic result (Table XV). Two patients still under treatment for pseudarthrosis were also omitted.

Patients rated as having good cosmetic results showed an average gain of 49 per cent. Those with fair results gained 21 per cent, while those with poor results showed an average gain of 4 per cent.

In the group of patients with paralytic scoliosis who were evaluated, 78 per cent were rated as having a good result. Without evidence of a pseudarthrosis at any time, 85 per cent had good results. With graft defects present there were 67 per cent good results, while of those in whom the defective fusion persisted, there were 43 per cent rated as having good cosmetic results.

Loss of Correction During Treatment

The average loss of correction in the series was 12 degrees (Table XVI). With pseudarthroses persisting, there was an average loss of 31 degrees.

TABLE XII

IDIOPATHIC SCOLIOSIS

Type of Fusion	No. of Cases	No. of Pseudarthroses	Percentage of Pseudarthroses
Gillette Hospital Series	98		
Early-type fusion	32	19	59
Cobb-type fusion	21	2	10
Articular-facet fusion	45	10	22
Autogenous bone	19	2	10
No bone added	17	6	35
Bone-bank bone	9	2	22
Private patient series	32		
Early-type fusion	2		
Cobb-type fusion	9		
Articular-facet fusion	21		
Autogenous bone	10		
Bone-bank bone	7		
No bone added	4		

TABLE XIII

CURVE PATTERNS IN 136 PATIENTS WITH PARALYTIC SCOLIOSIS

Pattern	No. of Cases	Per Cent
Right thoracic	25	19
Left thoracic	10	7
Right thoracolumbar	64	47
Left thoracolumbar	18	13
Right thoracic, left thoracolumbar	14	10
Left thoracic, right thoracolumbar	5	4

Incidence of Pseudarthrosis

There were 136 patients with paralytic scoliosis on whom 212 separate spine fusions were performed. There were thirty-seven operations for pseudarthrosis.

In the early type of fusion, the use of autogenous bone resulted in a 58 per cent incidence of graft pseudarthrosis. Of the twenty-six patients in this group of early fusion, the over-all percentage of graft defects was 65 (Table XVII).

TABLE XIV

AVERAGE PERCENTAGE GAIN IN PATIENTS WITH PARALYTIC SCOLIOSIS

	No. of Patients	Average Percentage Gain
Patients with paralytic scoliosis	115 *	44
Patients with solid fusions excluding those with pseudarthroses	67	47
Patients with pseudarthroses	48	39
Patients in whom pseudarthroses became solid	34	41
Patients with pseudarthroses persisting	14	29

* Two patients with pseudarthroses who are still under treatment are not included; nineteen double curves are separately analyzed.

TABLE XV

EVALUATION OF AVERAGE PERCENTAGE GAIN CORRELATED WITH COSMETIC EVALUATION IN PATIENTS WITH PARALYTIC SCOLIOSIS

Cosmetic Rating	No. of Patients	Average Percentage Gain
Total patients (115)		
Good	90	49
Fair	19	21
Poor	6	4
Patients with solid fusions excluding those with pseudarthroses (67)		
Good	57	51
Fair	8	26
Poor	2	4
Patients with pseudarthroses (48)		
Good	32	47
Fair	11	20
Poor	5	9
Patients with persisting pseudarthroses (14)		
Good	6	48
Fair	5	16
Poor	3	16

TABLE XVI

LOSS OF CORRECTION DURING TREATMENT IN PATIENTS WITH PARALYTIC SCOLIOSIS

	No. of Patients	Average Loss (*Degrees*)
Patients with paralytic scoliosis	115 *	12
All solid fusions	101	10
All fusions with persisting pseudarthroses	14	31
Fusions with pseudarthroses becoming solid	34	16
All solid fusions excluding pseudarthroses	67	7

* Two patients with pseudarthroses who are still under treatment are not included; nineteen double curves are separately analyzed.

TABLE XVII

EARLY-TYPE FUSIONS IN PATIENTS WITH PARALYTIC SCOLIOSIS

Type of Bone Added	No. of Cases	No. of Pseudarthroses	Percentage of Pseudarthroses
Autogenous bone	19	11	58
Bone-bank bone	3	2	67
Autogenous bone plus bone-bank bone	4	4	100
Total	26	17	65

The percentage of excellent results from solid fusions obtained by the Cobb technique in the patients with idiopathic scoliosis was not found in those with paralytic scoliosis. With autogenous bone added, pseudarthrosis was found in 36 per cent. Of the twenty-eight patients in this group, defects in the graft developed in 50 per cent (Table XVIII).

There were eighty-two patients in whom articular-facet fusion was performed; of these, there was pseudarthrosis in 30 per cent. Of the twenty-two patients in whom autogenous bone was added, pseudarthrosis developed in 14 per cent. Of the thirty-one patients in whom no additional bone was added, defective grafts developed in 42 per cent (Table XIX).

Statistical comparison of the private patients with those treated at Gillette Hospital is of little value except possibly in the group in which articular-facet fusion was used. In this group of sixty patients from Gillette Hospital, there were twenty-one patients with pseudarthroses (34 per cent). In twenty-one patients treated privately by articular-facet fusion there were five patients with pseudarthroses (23 per cent).

LOCATION OF PSEUDARTHROSIS

There has been recognition for years among orthopaedic surgeons of experience that the thoracic spine fuses solidly in a much higher percentage of patients than do the thoracolumbar and lumbar spines. The incidence of pseudarthrosis in patients with

TABLE XVIII

COBB-TYPE FUSIONS IN PATIENTS WITH PARALYTIC SCOLIOSIS

Type of Bone Added	No. of Cases	No. of Pseudarthroses	Percentage of Pseudarthroses
Autogenous bone	14	5	36
Bone-bank bone	8	6	75
Autogenous bone plus bone-bank bone	6	3	50
Total	28	14	50

TABLE XIX

ARTICULAR-FACET FUSIONS IN PATIENTS WITH PARALYTIC SCOLIOSIS

Type of Bone Added	No. of Cases	No. of Pseudarthroses	Percentage of Pseudarthroses
Autogenous bone	22	3	14
Bone-bank bone	25	7	28
Autogenous bone plus bone-bank bone	4	2	50
No bone added	31	13	42
Total	82	25	30

idiopathic scoliosis is known to be lower than that in those with paralytic scoliosis. The high incidence of curves limited to the thoracic spine in those with idiopathic scoliosis, in addition to the relative stability of these curves, contributes to the high occurrence of solid fusion. On the other hand, most curves in scoliosis caused by poliomyelitis involve a good deal of the lumbar spine, are more flexible and collapsing, and tend to be longer. The most vulnerable area for fusion defects in the spine is in the transitional area between thoracic and lumbar vertebrae.

In this group of patients with idiopathic and paralytic scoliosis, there were 135 separate pseudarthroses diagnosed. Several defects developed in many patients. In some, little evidence of the bone graft was found at the time of exploration, fibrous-tissue replacement being found instead. No explanation for this marked bone absorption has been found. In the typical pseudarthrosis there will be a heavy solid graft covered by periosteum which strips readily up to the area of pseudarthrosis where there is heavy fibrous tissue tightly adherent to the defective area. Occasionally, the pseudarthrosis will be well hidden and can only be located after removing an incomplete shell of apparently viable bone over it.

Most pseudarthroses can be detected by careful oblique roentgenographic study of the graft five or six months following fusion.

The incidence of graft defects according to location is shown in Figure 5. Above the sixth thoracic vertebra there were six pseudarthroses and above the tenth thoracic vertebra there were twenty-seven. Below the tenth thoracic vertebra the incidence rises sharply, fifty-three defects being found in the area between the eleventh thoracic and first lumbar vertebra. Below the third lumbar vertebra the incidence of pseudarthrosis diminishes. It is reasonable to suppose that this is to some extent due to the lesser number of spines fused below this vertebral body.

OPERATIVE MORTALITY AND MORBIDITY

In the group of 266 patients analyzed, there were 377 separate operations for spine fusion and sixty-nine operations for repair of pseudarthroses, a total of 446 operative procedures.

No operative deaths occurred. No instance of operative spinal-cord damage has been found. The overzealous use of electrocautery to control deep bleeding gave rise to nerve-root damage of a temporary nature in one patient.

ROENTGENOGRAPHY IN SCOLIOSIS

In recent years there has been increasing awareness of the danger inherent in overexposure to x-rays. This must be borne in mind when a patient with scoliosis is treated for years and is checked by a series of roentgenographic studies every few months. The author was impressed by the very large numbers of roentgenograms comprising the recorded progress of many of the earlier patients studied, particularly when several reoperations for pseudarthrosis became necessary. While no ill effects have become apparent

in any patient and while many of the earlier female patients of whom large numbers of roentgenograms were made have subsequently married and delivered normal children, the inherent danger of x-ray exposure should be kept in mind in dealing with the problem of scoliosis.

DISCUSSION

Selection of the Fusion Area

The portion of the spine to be fused, that with the major or primary curve, can usually be selected without difficulty; it may be of several types:

1. The center curve of a three-curve pattern (Fig. 6-A);
2. The uppermost of the two center curves of a four-curve pattern (Fig. 6-B);
3. The lower of the two center curves of a four-curve pattern (Fig. 6-C);
4. The two center curves of a four-curve pattern (Fig. 6-D).

The primary curve has the greatest length, the greatest structural changes, and demonstrates the least flexibility as seen in roentgenograms made with the patient bending to the side.

In Type 1, the major curve in idiopathic scoliosis is usually right thoracic or thoracolumbar, less often left thoracolumbar, and rarely, left thoracic.

In Type 2, the major curve is right thoracic, with a left lumbar curve. In anteroposterior roentgenograms made with the patient standing, sitting, or supine, these two center curves may be scarcely distinguishable from the true double primary-curve pattern. Roentgenograms made with the patient bending to the side prove that the thoracic curve is much less flexible than the lumbar curve. In this same pattern, early roentgenograms made when the curve is just beginning to progress show that the thoracic curve is assuming structural characteristics far in advance of the lumbar curve.

In Type 3, the primary curve is left thoracolumbar and roentgenograms made with the patient bending to the side prove that the right thoracic curve above is relatively flexible. This is an uncommon curve pattern.

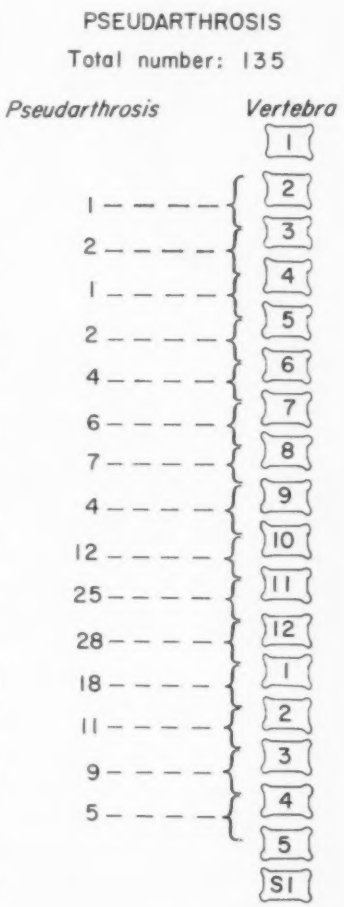


FIG. 5

In Type 4, the two center curves are equally structural from their beginnings and their flexibility diminishes equally with progression.

There are two criteria which determine the ends of any curve: (1) maximal vertebral tilting, and (2) paralleling or reversal of the intervertebral-space wedging.

The maximally tilted end vertebra can be determined at a glance of the practiced eye; those less experienced may need to draw lines along the vertebral-body margins in order to determine when these lines cease converging into the concavity of a curve and begin to diverge on the convex side of the adjacent curve. It follows naturally that the intervertebral spaces within a curve will be wedged to the concavity of a curve and that their wedging will be reversed in the opposite curve.

In determining the fusion area, several additional factors must be considered:

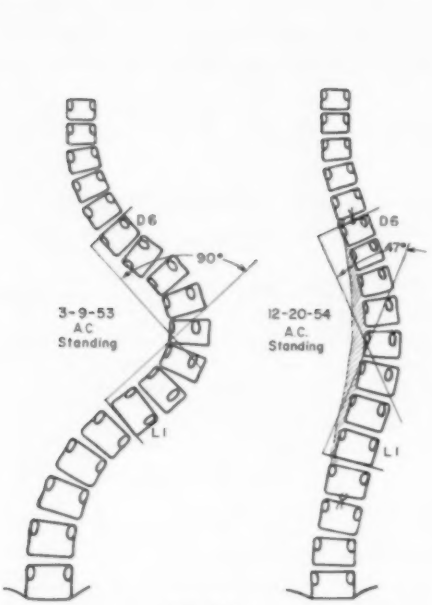


FIG. 6-A

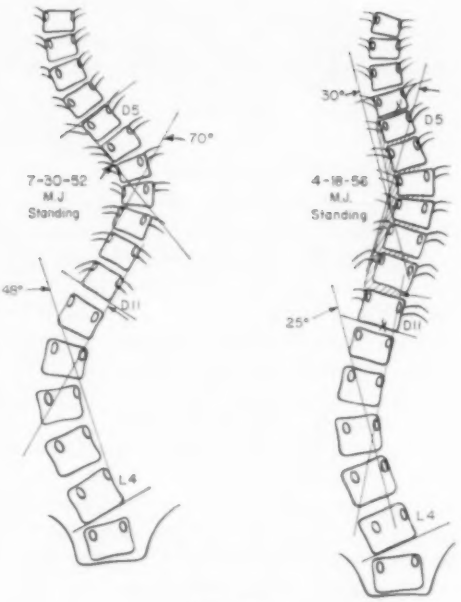


FIG. 6-B

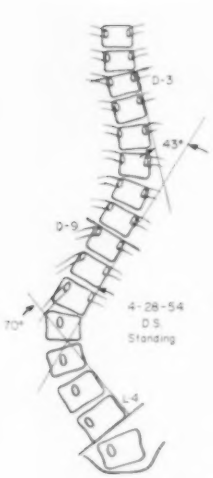
Fig. 6-A: A. C. This child had idiopathic scoliosis. The primary curve of the spine was to the right at 90 degrees, from the sixth thoracic to the first lumbar vertebra. When the patient was thirteen years old, the spine was fused from the sixth thoracic to the second lumbar vertebra. The curve was reduced to 47 degrees and correction has been maintained.

Fig. 6-B: In this child, M. J., with idiopathic scoliosis, the right primary curve of 70 degrees was from the fifth to the eleventh thoracic vertebra. There was a compensatory curve of the lumbar spine of 48 degrees and there were mild structural changes seen on roentgenograms made with the patient bending to the side. When the patient was twelve years old, spine fusion, limited to from the fourth to the eleventh thoracic vertebra, was done with reduction of the primary curve to 30 degrees. The correction has been maintained and the curve of the lumbar spine spontaneously reduced to balance the corrected thoracic portion of the spine.

1. *The Extent of Rotation of the Vertebral Bodies toward the Convexity of the Curve* (*Fig. 7*)

Vertebral rotation is present in any structural curvature and can be determined by noting the relationship of the oval pedicle shadows to the vertebral body. Because the spinous process is often difficult to visualize and because the pedicles are always readily seen, the latter are most often used in determining rotation. When the outline of the body extends farther beyond the pedicle on the convexity of a curve than it does on the concavity, that vertebra is rotated to the curve's convexity. When the two pedicles are equidistant from the vertebral margins on each side, that vertebra is not rotated, and may be called neutral. The rotation shown on roentgenograms may be changed by having the x-ray technician place the patient with pelvis and shoulders tilted against the film for an oblique view.

The ends of the measured curve, as determined by the maximally tilted vertebra, may coincide with termination of rotation; that is, the maximally tilted vertebra may also be neutrally rotated. On the other hand, it is frequently noted that the maximally tilted vertebra is still rotated to the convexity of the major curve and that such rotation continues for one, two, or even three vertebrae beyond the maximally tilted vertebra. In this event, the fusion area must be extended beyond the measured curve to include all vertebrae which are so rotated and to include as well the neutral vertebrae at each end of the curve. This is particularly true of the lower end of a major curve.



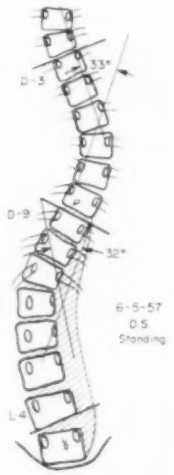
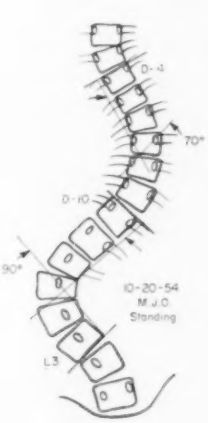


FIG. 6-C



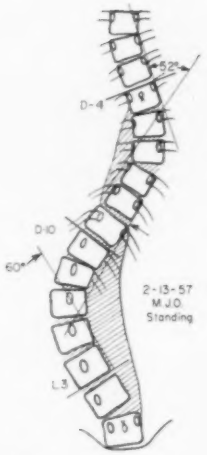


FIG. 6-D

Fig. 6-C: There was a primary left thoracolumbar curve of 70 degrees from the ninth thoracic to the fourth lumbar vertebra in this child, D. S., with idiopathic scoliosis. Mild structural changes were seen roentgenographically in the region of the right compensatory curve of the thoracic spine. When the patient was thirteen years old, the spine was fused from the ninth thoracic to the fifth lumbar vertebra (the addition of the fifth lumbar vertebra to the fusion area was probably unnecessary). The correction to 32 degrees has been maintained. The functional element in the right thoracic curvature permitted its spontaneous improvement in order to balance the corrected portion of the spine below. (If the deformity had been paralytic scoliosis in a younger patient, both involved portions of the spine would have required fusion.)

Fig. 6-D: M. J. O. In this twelve-year-old child with idiopathic scoliosis there is a double primary-curve pattern. Both curves are severely structural, although the left thoracolumbar curve is of a greater degree. Fusion of both portions of the spine in maximal balanced correction is necessary.

The first rule in selection of the fusion area is, therefore, to fuse all vertebrae which are rotated to the convexity of the major curve and to include the neutrally rotated vertebrae above and below. Roentgenograms made both before and after correction must be studied.

2. *The Location of the Curve and the Flexibility of the Opposite Curve* (*Fig. 8*)

If such continuing rotation is noted below a thoracolumbar curve in which the maximally tilted vertebra is the fourth or fifth lumbar, the fusion area will not have to include all of the rotated vertebrae. In such a curve, the lower neutral vertebra may be the sacrum. While not axiomatic, the rule may be stated that in scoliosis having the maximally tilted vertebra in the lower lumbar area, and having a short compensatory lumbosacral curve below, one may disregard rotation persisting below this maximally tilted vertebra.

When a thoracolumbar curve is the major curve and a partly structural curve is present above it, that portion of the spine with the upper curve must be fused in part or all of its total extent if the patient is young, for it may otherwise show progressive curvature which will decompensate the fused portion of the spine below. This is particularly true in paralytic scoliosis.

One frequently encounters the primary right thoracic curve in patients with idiopathic scoliosis, with the left lumbar curve below being somewhat structural (Figs. 9-A through 9-D). It must be pointed out that early roentgenograms will show the right thoracic curve first evident, and that while the lumbar curve below shows clinical evidence of being structural when the patient bends forward, it never becomes as inflexible as the thoracic curve above, and often demonstrates a surprising degree of flexibility in roentgenograms made with the patient bending to the side. In such a curve pattern, only the portion of the spine involved in the right thoracic curve needs fusion in partial correction; one must be sure to leave enough curve to balance whatever permanent structural curvature may be

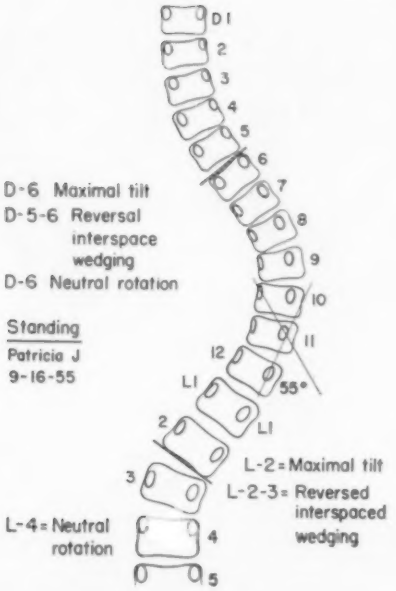


FIG. 7

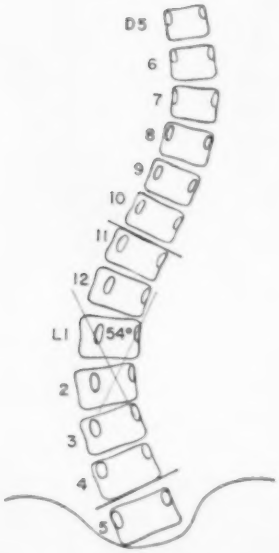


FIG. 8

FIG. 9-A

FIG. 9-B

Figs. 9-A through 9-D: Roentgenograms of M. H., a child with idiopathic scoliosis.
Fig. 9-A: The primary curve is to the right from the fifth to the eleventh thoracic vertebra.
Fig. 9-B: Roentgenogram made with the patient bending to the left shows that only 30 degrees of the lumbar curve is structural.

FIG. 9-C

FIG. 9-D

Fig. 9-C: The spine was fused when the patient was sixteen years old from the fourth to the twelfth thoracic vertebra resulting in maximal correction of the curve at 60 degrees.
Fig. 9-D: Complete compensation occurred when the curve in the lumbar spine spontaneously balanced the corrected portion of the thoracic spine.

present in the curve below and above, as shown by roentgenograms made with the patient bending to the side. The fusion of one vertebra above and below the measured curve will provide additional security that correction will not be lost through lengthening of the original curve. The rule to follow is: When in doubt, add a vertebra to the fusion area.

This problem is seldom encountered in patients with paralytic scoliosis. Here, the thoracic and lumbar curves tend to be equally structural; both these portions of the spine should be fused in balanced correction.

The true double primary curve of idiopathic scoliosis presents an obvious pattern from its onset. Both curves are equally structural and progressive. Both involved portions of the spine should be fused throughout the extent of the curves.

3. *The Age of the Patient*

There is no specific contra-indication to correction and fusion of the spine in the young patient with progressive scoliosis other than the presence of an already existing lordosis in the proposed fusion area. Early fusion does not appear to produce a loss of vertical growth of the spine which is of clinical significance. It is recognized that vertebral growth in height following fusion takes place at the expense of the intervertebral disc to some degree. It is also recognized that some degree of lordosis may occur in the fusion area, provided that the spine is very nearly completely corrected in its curvature and that a flat or slightly lordotic spine exists in the fusion area prior to surgery. It is wise to postpone fusion while maintaining some correction or at least preventing progress by means of a Milwaukee brace or Risser localizer cast in patients with idiopathic scoliosis in

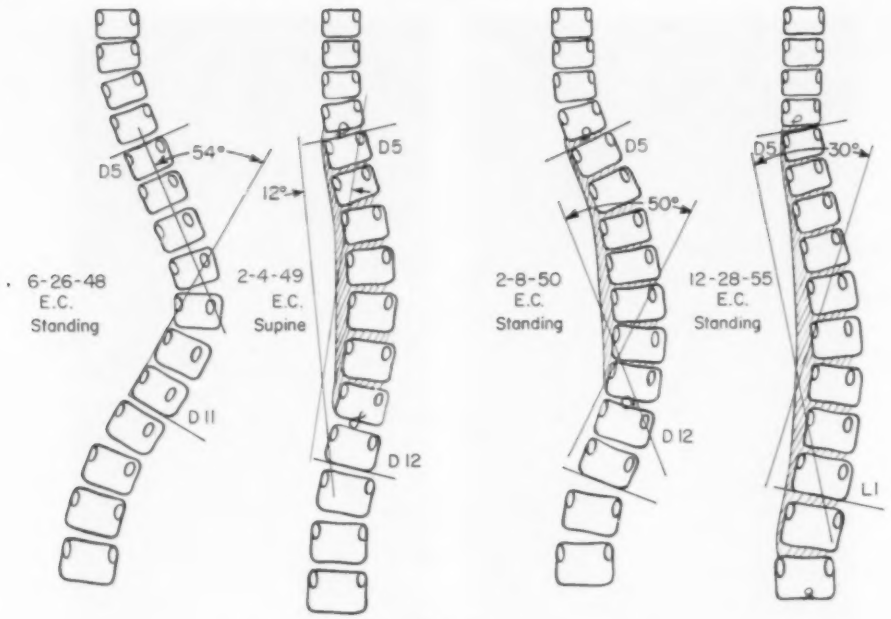


FIG. 10

This eleven-year-old child, E. C., was first seen in 1948 with idiopathic scoliosis. There was a right thoracolumbar curve from the fifth to the eleventh thoracic vertebra of 54 degrees. The curve was reduced to 12 degrees with the use of a turnbuckle cast. The spine was then fused from the fourth to the eleventh thoracic vertebra. However, the fusion area was too short at its lower end by at least three vertebrae since rotation to the second lumbar vertebra as seen by roentgenogram before correction continued. As a result the curvature re-appeared below the fusion area. Further correction by cast and extension of the fusion area to the third lumbar vertebra gave a satisfactory result.

whom the lateral roentgenogram demonstrates a flat thoracic spine with a narrow antero-posterior diameter of the chest. It is also wise to postpone fusion in the very young with paralytic scoliosis showing lordotic tendencies because the posterior spinal muscles are not functioning. Such contra-indications have arisen rarely in the author's experience.

Errors in selection of the fusion area in the young patient have arisen through failure to fuse a great enough portion of the spine, never through the addition of extra vertebrae in the fusion area. The rule to follow is therefore to add vertebrae to the fusion area when in doubt (Fig. 10).

Loss of Correction

Much has been written concerning loss of correction following spine fusion in the young patient. In the author's experience such loss of correction has not occurred without adequate reason. There are three main reasons for such loss in the young as well as in the older patient:

1. The fusion area was not of adequate length;

2. A pseudarthrosis in the fusion area was not discovered in time to prevent loss of correction;

3. In paralytic scoliosis, marked muscle inequality and fascial contracture or both may have persisted and caused pelvic obliquity to recur with unrelenting bending force upon the fused spine. The author has seen one patient with this combination of circumstances in whom the fused spine actually bent with growth, although it was unquestionably solid. One might question whether the fusion area was long enough in this patient, for re-evaluation suggests that loss of correction would not have occurred had the fusion

extended down to the sacrum. Other means also might have been used to prevent loss in such circumstances, including prolonged protection after fusion by the Milwaukee brace or Risser localizer cast. Pseudarthrosis need not mean permanent loss of correction even if unrecognized. The loss of correction can be regained in most instances and re-fusion can be successfully carried out (Figs. 11-A through 11-J).

Methods of Correction

Of methods of correction of the scoliotic spine, none has stood the test of time as has the turnbuckle cast of Risser and Hibbs. In beginning treatment of the series of patients presented in this survey, the author used the turnbuckle cast of Risser, as modified by Cobb. Excellent correction was obtained for the most part, with pressure ulcers only occasionally complicating the treatment. The length of time elapsing between the cast application and the fusion was usually six weeks or longer. A trial of rapid correction by the same method with freshly hardened plaster as hinges convinced the author that most curvatures could be corrected to the desired maximum at the time of cast application, with the operative window cut out at the same time, thus saving several weeks of hospitalization for the patient. Slow correction by metal hinges and turnbuckle was reserved for those in whom the scoliotic spine was most rigid. The incidence of bite deformities, from too much pressure against the lower jaw, lessened with increasing experience.

In 1952 the Risser localizer cast became the author's routine method of correction of scoliosis. Excellent correction was obtained for the most part, and, if further correction were thought desirable, it was obtained through use of the rapid-wedging principle, or by slow wedging by the insertion of hinges and turnbuckle.

Throughout the span of years covered in this survey, the Milwaukee brace of Schmidt and Blount was used on a substantial number of patients. The difficulty encountered was through failure to appreciate the snug fit required for maximal effectiveness of this brace. In spite of early poor fitting, correction was on the whole satisfactory. The author is impressed with the effectiveness of this brace, when properly made, in the correction of structural scoliosis. In order to obtain proper fitting it is necessary for the brace-shop personnel to become completely familiar with the technique of Milwaukee-brace construction, as outlined by Blount and Schmidt. Such specialized trained personnel may not be available to many orthopaedic surgeons, and for this reason, it is the author's opinion that the orthopaedic resident should become thoroughly familiar with the application of the Risser localizer cast and the wedging cast, so that he may most effectively treat patients with scoliosis, even though a brace shop skilled in the construction of the Milwaukee brace may not be available to him.

Many patients in this series have by necessity been subjected to many months of waiting before they could be admitted for final correction and fusion. During these months, most of the patients wore ambulatory Risser localizer casts and a few wore Milwaukee braces. In the young patients with progressing scoliosis such measures resulted in some benefit to the patient in obtaining maximum correction. In more severely structural scoliosis and especially in older patients, the author's experience leads him to believe that such pre-fusion attempts at ambulatory correction are disappointing, and that the best correction is obtained with the patient lying down. The author agrees with Blount and Schmidt in their belief that maximal correction in the Milwaukee brace can be obtained only with the patient in bed and horizontal. Likewise, in nearly all instances, maximal correction in the Risser localizer cast can only be maintained by keeping the patient in bed for a period of from four to six months. In this series, only those patients in whom the scoliosis was in the thoracic area and in whom it was nearly fully corrected could be allowed to be up postoperatively without loss of correction of 10 degrees or more. Since loss of correction of 10 degrees occurred in the average patient when kept supine postoperatively, the author did not feel that the benefits of ambulation were sufficient to warrant an addi-

FIG. 11-A

FIG. 11-B

FIG. 11-C

FIG. 11-D

FIG. 11-E

FIG. 11-F

Figs. 11-A through 11-J: Roentgenograms and photographs of a patient with paralytic scoliosis demonstrate that pseudarthrosis does not necessarily cause permanent loss of correction.

Fig. 11-A: C. T., aged thirteen years and two months. The spine was curved 74 degrees to the right from the eighth thoracic to the third lumbar vertebra.

Fig. 11-B: Correction to 25 degrees was obtained by use of the wedged Risser localizer cast.

Fig. 11-C: Eleven months after spine fusion, no evidence of pseudarthrosis is seen on this anteroposterior roentgenogram. The spinal curve was 35 degrees and the plaster cast was removed.

Fig. 11-D: After three months without support, there was loss of correction to 50 degrees and clear evidence of a pseudarthrosis between the eleventh and twelfth thoracic vertebrae.

Fig. 11-E: Roentgenogram made after further correction with a wedging cast. The pseudarthrosis is clearly visible.

Fig. 11-F: Three years after repair of the pseudarthrosis the fusion is solid and correction is close to the original maximum of 25 degrees.

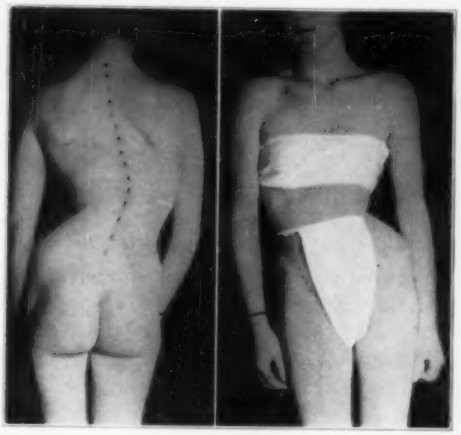


FIG. 11-G

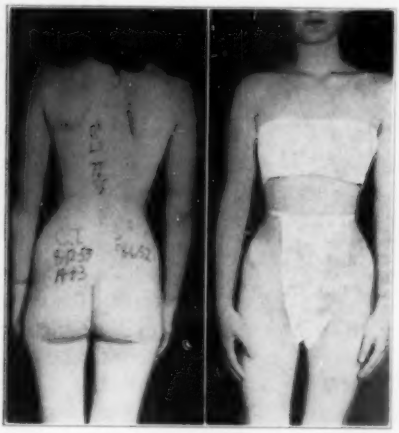


FIG. 11-H

Fig. 11-G: Photographs made on March 12, 1952, before treatment was instituted.

Fig. 11-H: Photographs made when the cast was removed, August 12, 1953.

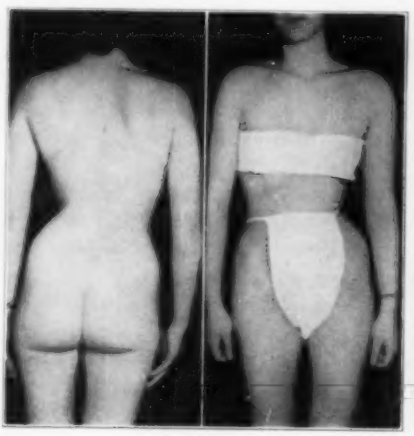


FIG. 11-I

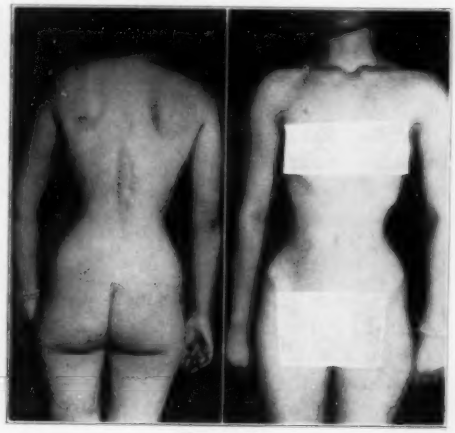


FIG. 11-J

Fig. 11-I: Loss of correction due to the pseudarthrosis was evident on February 19, 1954.

Fig. 11-J: Photographs made on October 10 1956, two and one-half years after the second correction of the scoliosis and repair of the pseudarthrosis.

tional 10 to 15 degrees further loss of correction. Such loss on ambulation has occurred in spite of the most rigorous adherence to Risser's technique of the application of a skin-tight, well molded cast.

Preoperative and Postoperative Management

A reasonably fixed routine has developed in the author's experience during the past several years in the preoperative and postoperative management of scoliosis. On admission to the hospital, the patient is scheduled for application of the cast the following morning unless further study is indicated. The cast is applied to the patient with his stomach empty and under moderate sedation. A maximum effort is made to obtain the desired correction (50 per cent or more). The technique followed in cast application is that of the localizer cast as described by Risser. The cast is windowed in front and back. The posterior operative window is reinforced with enough plaster to make the cast secure beyond doubt. Roentgenograms are made with the patient supine and the curve is measured on the wet film. If correction is less than desired the windowed cast can be wedged immediately, or this can be deferred to a later postoperative date, depending upon the patient's ability to tolerate further correction.

The operative fusion is carried out in one or two stages, two weeks apart. The average number of vertebral interspaces fused at one time is eight. Since initial cast application usually gives satisfactory correction, the cast was not routinely changed postoperatively. It is so changed if further correction is desirable, usually with wedging. The author was not impressed with the loosening of the vertebrae by the spine fusion itself, and routine postoperative change of the localizer cast did not give correction further than that obtained by the initial maximal effort in the average patient.

Assuming that the desired correction has been obtained and that the patient is comfortable, he is discharged from the hospital a week or ten days after surgery is completed. The patient is instructed to remain horizontal, but may turn and move about in bed at will. The torso may be elevated to a 40-degree angle from the horizontal without harm. The parents are instructed in the care of the cast. Exercises to be performed in bed are outlined. In the average case, the patient returns for the first cast change in six months. At that time the cast is removed and the spine is studied roentgenographically on fourteen by seventeen-inch films in both oblique views and in the anteroposterior view. A lateral roentgenogram at this time was not found helpful. These roentgenograms are carefully studied for evidence of pseudarthrosis. A new localizer cast is applied, again with maximal snugness and molding. Windows are cut in front and back to allow ventilation. If the fusion appears intact, the patient may then be allowed to be up increasingly to relatively full activity. A roentgenogram with the patient standing is made two weeks after ambulation is begun.

The full localizer cast is worn for three months more. The cast is then again removed and roentgenographic studies repeated. If the fusion appears solid and mature, a snug body cast is applied and worn for two more months. If there is no loss of correction, the patient is then allowed to be active without external support.

Some variation exists in this routine. The whole program of immobilization can be shortened by one or two months if the child is below the age of nine years and has no precocious growth. If a six-month check reveals an obviously defective graft, it is explored and re-fused without further delay, the patient being kept down in the full localizer cast. Suspicious defects are watched for an additional two months, during which walking is not allowed.

In patients with paralytic scoliosis with pelvic obliquity, every attempt is made to overcome the obliquity through release of tight structures and postoperative stretching according to the Irwin technique. In applying the localizer cast in these patients, the author has found it imperative to overcorrect the pelvic obliquity by skeletal femoral traction incorporated into a spica extension of the cast, if the fusion is not to extend down to the sacrum. Patients with paralytic scoliosis of a mild degree with abdominal muscular inequality should have Lowman fascial bands inserted before the spine is cor-

rected and fused. In the presence of severe structural curvatures, such transplants must be delayed until the spine has been adequately corrected and fused.

Patients being treated in the Milwaukee brace follow a somewhat different routine. Since the brace is removed for surgical fusion, it follows that correction must be obtained postoperatively. It is therefore necessary to keep the patient in the hospital for a slightly longer period until, through adjustment of the brace, sufficient length of the spine is obtained for maximal correction. When that correction is attained the patient may be at home, but should return at regular intervals for brace inspection. The patient is kept supine until the fusion is solid, a period of from five to six months. The brace is worn until the fusion is mature, a period of from ten to twelve months.

SUMMARY

Idiopathic Scoliosis

One hundred and thirty patients with idiopathic scoliosis were treated by three methods of fusion. The average gain in correction was 40 per cent. In the absence of pseudarthroses, the average gain was 43 per cent. Patients with pseudarthroses showed an average gain of 22 per cent and those with persistent defects showed an average gain of 13 per cent.

Patients rated as having a good cosmetic result showed an average gain of 45 per cent, while those rated as poor gained only 5 per cent.

Fusions performed in the early years of this series resulted in 56 per cent of defective bone grafts. The Cobb method of fusion resulted in pseudarthroses in only 7 per cent. Articular-facet fusions resulted in pseudarthrosis in 15 per cent but in the group in whom autogenous bone was added, defective grafts developed in only 7 per cent.

Paralytic Scoliosis

One hundred and thirty-six patients with paralytic scoliosis were treated in whom the average gain in correction was 44 per cent. With no pseudarthrosis present, the average gain was 47 per cent. Patients having defective grafts averaged 39 per cent gain and those with persistent defects averaged 29 per cent gain in correction.

Patients rated as having a good cosmetic result showed an average gain of 49 per cent while those with poor results showed a 4 per cent gain in correction.

Of the patients in whom early fusions were done, there were pseudarthroses in 65 per cent. Cobb-type fusions with autogenous bone added resulted in pseudarthrosis in 36 per cent, while in articular-facet fusions, there was an incidence of pseudarthrosis of 14 per cent when autogenous bone was added.

CONCLUSIONS

Correction and fusion of the scoliotic spine is productive of results entirely satisfactory cosmetically and functionally provided that the proper fusion area is selected and the graft becomes solid and mature. Pseudarthrosis is the prime reason for loss of correction. Most pseudarthroses can be discovered, repaired, and protected until solid without appreciable loss of correction. A meticulous fusion with wide exposure, with all soft tissue removed from the posterior surfaces of the spine, with decortication carefully and completely done, and with articular facets carefully fused, is productive of the best over-all results.

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DISCUSSION

Dr. Walter P. Blount, Milwaukee, Wisconsin: One should note the superiority of the results in the patients operated on by Dr. Moe himself. Thirty-two patients with idiopathic scoliosis in whom there was no pseudarthrosis must be a record. These results suggest that details of technique are of the greatest importance.

It is not too difficult to obtain the desired correction of scoliosis if it is treated early before the spine has become rigid. The exact technique of postoperative immobilization makes little difference in the final result. The common problem for all orthopaedic surgeons is the loss of correction due to pseudarthrosis.

Dr. Moe has modified his technique so that his more recent results have been excellent. His is a painstaking and laborious method, but he has perfected it so that the operating time is reasonable. The effort is worth while for all of us if it improves the end results. No detail of technique is too much trouble if it ensures a solid mature graft in a reasonably short time. To be truly strong in the thoracic spine the fusion area should extend from the cartilaginous cap of one transverse process across to the cartilaginous cap of the other and should extend anteriorly to include the articular facets. This rod of bone must be of sufficient diameter to resist bending forces that produce stress fractures months or years later.

Resection or destruction of the articular facets is desirable, but this alone is not sufficient to produce solid arthrodesis. Additional autogenous-bone grafts are necessary. The meticulous technique of Hibbs utilizes slivers from the spine itself. In most cases, autogenous bone from the ilium should be added. I too have given up the use of homogenous bone, even in small quantities. I know from the operative findings in numerous cases that the addition of large quantities of homogenous bone produces a shell-like graft which may look deceptively good on the surface but the central portion is isolated from the blood supply. Homogenous bone has changed to fibrous tissue, not new bone, with pseudarthroses in a high percentage of cases.

(Continued on page 646)

A Follow-up Study of the Treatment of Scoliosis*

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The most effective treatment of scoliosis for the past forty years has been surgical immobilization of the complete area of the lateral curvature. Spine fusion was first used in a scoliotic patient by Hibbs in 1914.

This paper will present a follow-up study of patients with scoliosis who were treated at the Los Angeles Orthopaedic Hospital from 1935 to 1950 and of patients from private practice from 1935 to 1956.

HAZARDS OF SPINE FUSION

In any surgical treatment we are concerned about possible fatalities. Of 347 patients with scoliosis in whom 619 spine fusions were done, there was one fatality. This occurred in a fourteen-year-old girl in 1936 before postoperative blood transfusion was routinely done. The extremes of age at the time of operation were from one and one-half years to thirty-nine years. There were thirteen patients under five years of age and sixteen over twenty years of age. This is evidence that age is not a factor as regards mortality (Table I).

TABLE I

CASES BY AGE AT SPINE FUSION *

	Number
Under five years	13
5 to 10 years	40
10 to 15 years	197
15 to 20 years	81
20 years and over	16
	347

* Youngest patient operated upon was one and one-half years; the oldest patient operated upon was thirty-nine years.

A second hazard is postoperative paralysis. In three patients in this series paraplegia developed following spine fusion. All had a severe kyphos associated with a lesser curve. In two, scoliosis was caused by neurofibromatosis and in one by Morquio's disease. Exploration and decompression were done in two patients—one two days after the operation and one a month after the operation. Partial recovery from paralysis was obtained. The third patient, not subjected to decompression, still has paraplegia. A laminectomy at the time of spine fusion would probably have obviated this disaster.

TECHNIQUES

The method used in measuring the lateral curvature of the spine is that described by Ferguson: "At each end of a curve the vertebra which is least rotated and nearest to being in neither one curve nor another is selected as the end vertebra. At the crest of the curve, the most rotated vertebra is selected as the apex. In each of these three vertebrae the center of the shadow of the body is marked in pencil. Lines are drawn from the apex to each end. The angle of the curve is the divergence of these two lines from 180 degrees." This is a true measurement of the curvature and reads less in degrees than other conventional methods. The limit of error is considered to be 2 to 3 degrees (Figs. 1-A, 1-B, and 1-C).

The method of spine fusion used was the Hibbs subperiosteal dissection. Following curettement of the posterior articulations, lamino-spinal osteal flaps were imbricated over

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 29, 1957.

FIG. 1-A

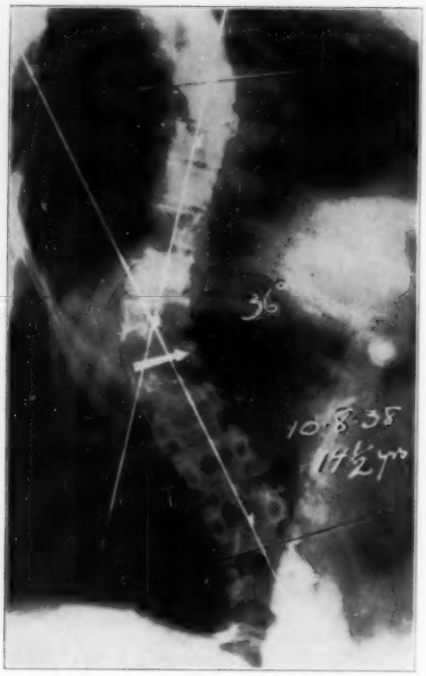

FIG. 1-B

Fig. 1-A: H. B., a girl, fourteen years old had had poliomyelitis at the age of eight. The iliac epiphysis has fused. Scoliosis is severe but static. This anteroposterior roentgenogram made with the patient standing shows the curvature before correction.

Fig. 1-B: Correction in a turnbuckle jacket from 75 degrees to 36 degrees. Fusion was done from the seventh thoracic to the third lumbar vertebra.

It is essential to locate accurately the area to be fused. A lead marker is fixed with adhesive tape over the tip of a prominent spinous process in the area to be fused. A roentgenogram is made with the lead marker in place to identify the spinous process beneath the marker. At operation, when the skin is being prepared, the marker is removed and a superficial, horizontal cut is made in the skin at the site of the marker. The vertebrae to be included in the fusion are determined exactly from the roentgenogram counting upward and downward from the vertebra identified by the lead marker. At operation the same number of spinous processes are counted off both upward and downward from the spinous process marked now by the skin cut. The vertebrae so identified are included in the fusion. Some surgeons prefer to identify a spinous process by inserting a hypodermic needle into the bone with the area anaesthetized. This is a more positive method of identification in the roentgenogram and at operation.

the interlaminal space. More recently we have elevated the posterior half of the lateral facet. The base of the transverse process was turned under the raised posterior facet. Any remaining portion of the transverse process and laminal and spinal flaps were imbricated over the area of the facet. However, in twenty of the patients, extra bone from the tibia was used.

The forces used in the correction of scoliosis by means of the turnbuckle cast are: (1) head and pelvic traction (parallel traction) which corrects angulation between the vertebrae involved in the curvature and (2) lateral bending of the spine which corrects rotation of the apical vertebrae. With the anteroposterior hinges of the jacket placed eccentrically over the apex of the curvature, both forces are utilized. Greater traction and less lateral bending are obtained when the hinges are placed more laterally away from the mid-line, while less traction and more lateral bending result when the hinges are placed near the mid-line or toward the concavity of the curve. Because of the severe lateral bending of the trunk produced during correction in the turnbuckle cast, walking is difficult.

A second method of correction of scoliosis makes use of the localizer cast. The term *localizer* is used to emphasize the third force used in the correction of scoliosis. This is obtained by pressure over the prominent posterior rib deformity which develops on the

side of the convexity of the curve. Posterolateral pressure applied to this rib prominence produces a corrective force through the ribs in the plane of the curve. This corrective force is, therefore, more efficient and less lateral bending is required than with the turnbuckle cast. However, if vertebral rotation is to be corrected some lateral bending must be used. Localizer correction maintains the spine in more or less alignment, thus making walking relatively easy. Maximum correction of severe curves can be obtained by means of the localizer cast if one or more preoperative casts are applied at intervals of two to four weeks (Fig. 4).

The corrective turnbuckle cast is used postoperatively for three months with the patient recumbent. Following the removal of this cast a supporting cast is applied and the patient is allowed to be ambulatory. The total time in a plaster cast is from six to fifteen months, the average being nine months. No other support is used following the removal of the last cast. As long as the fusion is not considered strong enough to maintain the correction without external support, a cast is maintained. Conversely when the fusion is strong enough to maintain the correction by itself, no further support of the spine is necessary.

FIG. 1-C

A roentgenogram made with the patient standing three years after correction and fusion from the seventh thoracic to the third lumbar vertebra. Note the relaxation or automatic correction of the lower lumbar curve, from 45 degrees before correction of the thoracolumbar curve to 9 degrees after correction of the thoracolumbar curve.

When the localizer cast is used, it is changed seven to ten days postoperatively and the patient is then allowed to walk. A very snug-fitting postoperative cast is necessary in order to maintain all possible correction when the patient is erect. A loss of 2 to 3 degrees of correction with the patient standing in a localizer cast is acceptable. If greater loss of correction is observed, the cast is inadequate. The postoperative localizer cast may be changed at intervals of three to four months. Since the localizer cast is corrective there is less frequent loss of correction. A localizer cast with a headpiece or high neck piece has proved to be the most effective. Casts extending up to the axilla only are not effective even in lumbar curves. It is sometimes convenient during preoperative correction to wedge some localizer casts, particularly in small children, rather than to apply a new cast for further correction. Postoperatively the usual localizer cast is applied.

MATERIAL

This particular follow-up study concerns only patients with scoliosis resulting from poliomyelitis and patients whose curves were of uncertain etiology and which, therefore, were termed *idiopathic*. Because there was much evidence in these patients with idiopathic scoliosis pointing to metabolic deficiencies, the disorder will be referred to as metabolic.

There were seventy-five patients with scoliosis resulting from poliomyelitis, almost equally divided between males and females, and 167 patients with metabolic scoliosis.

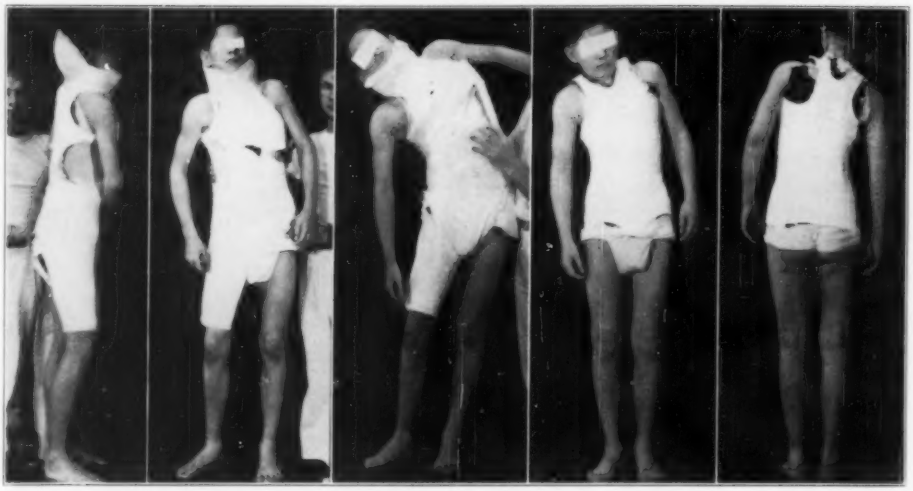

FIG. 2-A FIG. 2-B FIG. 2-C

Fig. 2-A: Turnbuckle cast prepared for wedging. The hinges are placed on the front and back of the cast over the apex of the curve on the side of the convexity. Hence they are placed eccentrically toward the side of the convexity toward which lateral bending takes place. A turnbuckle is placed on the cast on the side of the concavity to maintain bending correction.

Fig. 2-B: Complete correction accomplished. Turnbuckle cast reinforced for surgery. Ambulation not feasible.

Fig. 2-C: A supporting semi-bent cast is applied after the removal of the turnbuckle cast, three months after operation.

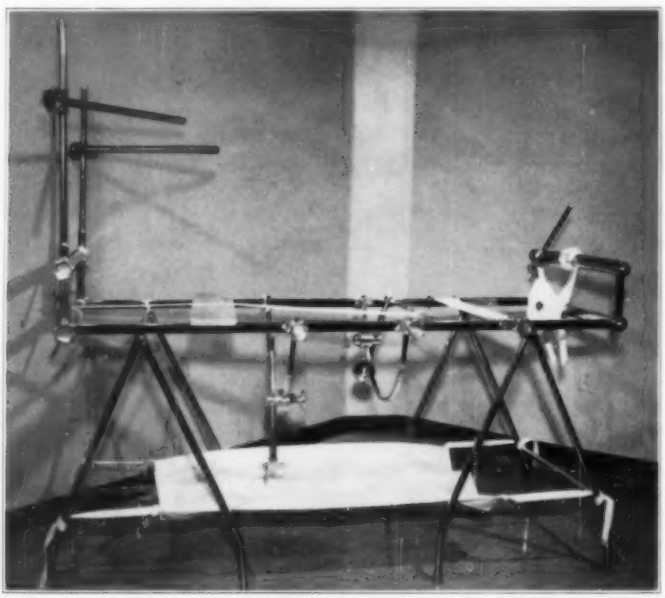

FIG. 3

Table used for the application of both the turnbuckle and the localizer body casts.

TABLE II
FOLLOW-UP OF TURNBUCKLE CASES

Number of Years	Number of Cases
1 to 5 years	76
5 to 10 years	63
10 to 15 years	18
15 to 20 years	10
20 years and over	1
	183 *

* Fifteen cases not included had no follow-up or a follow-up of under one year.

TABLE III
FOLLOW-UP OF LOCALIZER CASES

Number of Years	Number of Cases
Under 1 year	8
1 year	11
2 years	18
3 years	15
4 years	7
	59

When the cast was removed thirty-one patients treated with the localizer cast had not completed their growth. At the time of follow-up examination all had completed their vertebral growth except nine. Of these nine one is now deceased and the remaining eight are still being followed concomitantly with other localizer patients.

Only one-fifth of these were male. The average postoperative follow-up period was six years, the longest being twenty years. Seventy-six patients were followed for less than five years (Table II). The follow-up of the patients treated by means of the localizer cast was from six months to four years (Table III).

There are two objectives in the treatment of scoliosis: (1) to prevent increasing deformity and (2) to correct the deformity and to maintain correction. Since increase of the scoliotic deformity occurs with growth of the spine, prevention must begin with the mild curves before vertebral growth is completed. The progress of vertebral growth is determined from observation of the osseous development of the iliac epiphysis.

This follow-up study showed that 171 patients had not completed their spinal growth when treatment was started and hence increasing deformities were possible. In this group we observed only two patients whose deformities at follow-up examination were worse than at the start of treatment. Prevention of increasing deformity was not a problem in seventy-one patients in this study in whom vertebral growth was complete at the start of treatment. Correction of the existing deformity and the maintenance of this correction was the problem in both groups.

FIG. 4

Localizer body cast. The patient is ambulatory.

SELECTION AND MEASUREMENT OF THE FUSION AREA

In the treatment of patients with scoliosis, the most deforming curvature was selected for correction and fusion

FIG. 5-A

FIG. 5-B

Fig. 5-A: N. MC. A fourteen-year-old girl with two deforming structural curves due to poliomyelitis. Preoperative roentgenogram made with the patient standing. Both curves were corrected with the same localizer cast, and fusion was carried out from the fourth thoracic to the fourth lumbar vertebra. The fusion was done in two stages, two weeks apart. No iliac epiphysis is visible, indicating incomplete vertebral growth with increasing scoliosis (arrow). The cartwheel markers indicate the apices of the two curves and the neutral vertebra between them.

Fig. 5-B: Roentgenogram made with the patient standing four years after localizer cast correction and Hibbs fusion; the iliac epiphysis is now almost fused. Note that there is maintenance of good correction.

(Figs. 5-A and 5-B). With double curves, the most deforming was usually in the thoracic region. However, if both thoracic and lumbar curve were severely deformed, both were corrected and fused. In every case our objective was to attain as much correction as possible. If the curve was mild enough to allow overcorrection at its apex, fusion was not considered to be indicated and conservative treatment by means of localizer casts applied at intervals was used throughout the remainder of the growth period.

The area to be fused should be determined on the basis of the original roentgenogram made with the patient standing in which the deformity is most severe and also on the basis of the roentgenogram showing the correction obtained. As a general rule the fusion area should extend between the neutral vertebrae at each end of the curve. The neutral vertebrae show neither angulation nor rotation of the vertebral bodies in the anteroposterior roentgenogram. In some patients in whom compensatory lumbar curves are inadequate, rotation may extend downward farther than the angulation. Under these circumstances the fusion should include all of the rotated vertebrae.

If the correction has produced much disalignment of the spine as the result of lateral bending, as in the turnbuckle cast, the neutral vertebra at the lower end of the curve may show overcorrection. The fusion then should not include this overcorrected vertebra unless this overcorrection is considered necessary to compensate for the residual deformity of the curve being corrected.

Lateral bending when correction has been less extreme is obtained in the localizer cast. With this method the spine is in better alignment at the time of fusion. Overcorrection of the end vertebra is not produced and the fusion area can be carried down to include

FIG. 6-A

FIG. 6-B

Fig. 6-A: P. B., a thirteen-year-old girl. Roentgenogram was made with the patient standing. Note that no iliac epiphysis is visible (arrow) indicating incomplete vertebral growth and further possible increase of the deformity.

Fig. 6-B: Anteroposterior roentgenogram of the same patient lying down, showing recumbent correction of 10 degrees.

Fig. 6-C: Localizer correction with a Hibbs fusion from the fourth thoracic to the eleventh thoracic vertebra. Note slight loss of correction at the eleventh and twelfth thoracic vertebrae where the fusion area was short one vertebra. Total correction in this patient was 50 per cent, divided into 10 degrees recumbent correction and 20 degrees forcible correction.

FIG. 6-C

the neutral vertebra, or one vertebra beyond, in order to compensate for the residual deformity of the curve being corrected.

The severity of the original deformity is determined from an anteroposterior roentgenogram made with the patient standing. The final estimate of the deformity is determined from a comparable anteroposterior roentgenogram.

The severity of the curve is less as seen in the roentgenogram made with the patient recumbent. The amount of correction varies with the flexibility of the spine. In early thoracolumbar curves it may approach 20 degrees. In adults the correction obtained in recumbency may be very little or none at all as the amount of recumbent deformity approaches that of the weight-bearing deformity. The amount of forcible correction obtainable is likewise dependent upon the

TABLE IV

RECUMBENT AND FORCIBLE CORRECTION TURNBUCKLE AND LOCALIZER

	Number Curves	Average Original Standing (*Degrees*)	Average Recumbent Correction (*Degrees*)	Average Forcible Correction (*Degrees*)
Turnbuckle	68	51	10	19
Localizer	20	53	11	18
Both	88	51	10	19
		(Extremes:	2 to 24	8 to 32)

flexibility of the spine. The degree of flexibility is indicated by the change in curvature between the weight-bearing and recumbent positions as shown by roentgenograms. Observation of the amount of correction obtained in many patients has shown that forcible correction increases the correction by an amount approximately equivalent to twice that observed in recumbent position. The total correction to be expected therefore is generally equal to the sum of the recumbent correction and of the forcible correction. We found that the average recumbent correction as seen roentgenographically in eighty-eight patients was 10 degrees with a range from 2 to 24 degrees (Table IV).

TABLE V

COMPARISON OF RESULTS IN METABOLIC SCOLIOSIS AND IN POLIOMYELITIC SCOLIOSIS

Severity of Original Curve	Average Correction		Average Correction	
	Metabolic (*Degrees*)	Poliomyelitic (*Degrees*)	Metabolic (*Per cent*)	Poliomyelitic (*Per cent*)
0 to 25 degrees	16	11	81	67
25 to 50 degrees	24	28	66	75
50 degrees and over	31	33	49	52
Average of all	26	28	61	64
Total No. of Cases	167	75		

CORRECTION

The amount of correction obtainable in scoliosis is dependent upon the flexibility of the spinal joints. The first evidence of a scoliotic deformity visible in the roentgenogram is angulation between adjacent vertebrae. With increasing angulation, rotation of the apical vertebrae develops as a concomitant part of normal lateral bending of the spine. When this angulation occurs during growth, asymmetrical vertebral growth follows. This occurs because the end plates of the angulated vertebrae are not parallel, and growth

TABLE VI

COMPARISON OF RESULTS IN METABOLIC SCOLIOSIS AND IN POLIOMYELITIC SCOLIOSIS

Type of Curvature	Average Correction		Average Correction	
	Metabolic (*Degrees*)	Poliomyelitic (*Degrees*)	Metabolic (*Per cent*)	Poliomyelitic (*Per cent*)
High thoracic	15	15	36	57
Thoracic	25	26	59	55
Thoracolumbar	31	32	67	69
Lumbar	24	29	75	84
Average of all	26	28	61	64

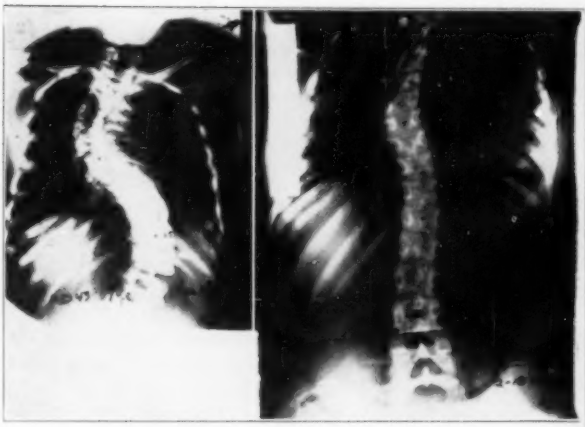

FIG. 7-A

FIG. 7-B

Fig. 7-A: E. J. A child seven years of age with severe thoracic and lumbar curves, before (left) and after (right) treatment with a turnbuckle cast and spine fusion from third thoracic to fifth lumbar vertebra. Greater correction was obtained in the more flexible lumbar region.

Fig. 7-B: E. J. Ten-year follow-up. Note maintenance of correction and the normal height of the vertebrae in the fusion area. The fusion mass has elongated as the vertebral bodies completed their development in height.

is greater on the convex side of the curve where the vertebral surfaces are separated with resultant decreased pressure on the vertebral end plates. This asymmetrical growth causes a lateral wedging of the vertebral bodies involved. The structural deformity is not corrected by treatment with a plaster cast and fusion. Correction is possible only in the presence of flexibility. The average observed flexibility permits about 25 degrees of correction, depending on the age of the patient and the chronicity of the curve. Therefore a 60-degree curve can be corrected by about 25 to 30 degrees (50 per cent), while a 30-degree curve can be corrected by about 25 degrees (83 per cent). Correction in patients with metabolic and poliomyelitic scoliosis was about equal (Table V). Greater correction was obtained in the more mobile lumbar and thoracolumbar regions than in the thoracic region (Table VI) (Figs. 7-A and 7-B). More absolute correction was often obtainable in the severe curves than in the milder ones, but the best relative correction, expressed in percentage of the original curve, was obtained in the milder deformities (Table VII). The turnbuckle cast produced a slightly greater average correction than did the localizer cast (2 to 5 degrees) (Table VIII). A second or third localizer cast was necessary to gain maximum correction.

The correction obtained by the turnbuckle jacket was slightly better than the correction obtained by the localizer cast (Table VII). However, of the patients who had excellent results, 25 degrees or more correction was maintained in 68 per cent of those treated with the localizer cast, whereas, in only 51 per cent of those treated with the turnbuckle jacket was 25 degrees or more of correction maintained. This indicates that the postoperative localizer cast is corrective as well as supportive and maintains better correction than the supportive cast used after the removal of the turnbuckle jacket. Loss of forcible correction and even recumbent correction in the patients with results classified as *fair* and *poor* must be explained on the basis of fusion which is inadequate as to length or as to strength. If this loss occurred while the patient was wearing the postoperative cast, we must conclude the postoperative support was inadequate. The two patients with poor results following turnbuckle correction had final curves which were

TABLE VII

AVERAGE CORRECTION EXPRESSED IN DEGREES AND AS PERCENTAGE OF THE ORIGINAL DEFORMITY CORRELATED WITH THE SEVERITY OF THE CURVE

Severity of Curve	Average Correction		Average Correction	
	Turnbuckle (*Degrees*)	Localizer (*Degrees*)	Turnbuckle (*Per cent*)	Localizer (*Per cent*)
0 to 25 degrees	15	10	77	68
25 to 50 degrees	26	23	72	60
50 degrees and over	32	31	50	52
Average of all	28	24	64	58

worse than the original. This happened because vertebral growth was not complete at the time of fusion and the cause of increasing deformity, namely a short fusion or a weak fusion, was not corrected.

RESULTS OF TREATMENT

In evaluating the results of treatment the following scale was used:

Excellent: total correction* of more than 20 degrees maintained;

Good: total correction of from 10 to 15 degrees maintained;

Fair: some or all of 10 degrees average recumbent correction maintained;

Poor: no correction maintained or condition became worse.

Results in patients in whom neither forcible nor average recumbent correction was maintained were rated *poor*. Results in those in whom some or all of the average recumbent correction was retained were classified *fair*. In those in whom all the average recumbent correction and up to 10 degrees of forcible correction were maintained, the results were considered good. Patients with all the average recumbent correction and forcible correction of more than 10 degrees maintained were considered to have excellent results. Since the average correction obtainable in all curves is roughly 25 degrees, a curve of 30 degrees which is reduced to 5 to 10 degrees has a correction of 65 to 80 per cent, whereas a 60-degree curve which is reduced by 25 to 30 degrees has a correction of 40 to 50 per cent. By the rating system used here the result in the 30-degree curve would be classified *good* with 20 to 25 degrees of correction while the result in the 60-degree curve with a correction of 25 to 30 degrees would be classified *excellent*. However, in terms of percentage of correction obtained the 30-degree curve was improved 65 to 80 per cent. This result should really be excellent, while the result in the 60-degree curve with only 40 to 50 per cent correction should be classified as good. To avoid this apparent discrepancy in the rating system employed, the two higher classifications of good and excellent have been grouped

TABLE VIII

AVERAGE CORRECTION EXPRESSED IN DEGREES AND AS PERCENTAGE OF THE ORIGINAL DEFORMITY CORRELATED WITH THE LOCATION OF THE CURVE

Type of Curve	Average Correction		Average Correction	
	Turnbuckle (*Degrees*)	Localizer (*Degrees*)	Turnbuckle (*Per cent*)	Localizer (*Per cent*)
High thoracic	17	11	50	42
Thoracic	25	23	58	56
Thoracolumbar	32	30	68	64
Lumbar	25	26	79	64
Average of all	28	24	64	58

* Total correction is defined as 10 degrees, the average recumbent correction plus the forcible correction obtained.

TABLE IX

RESULTS

	Turnbuckle		Localizer	
	No.	Per cent	No.	Per cent
Total	177	100	62	100
Excellent	57*	32	19**	30
Excellent and good	127	72	48	77
Good	70	40	29	47
Fair	42	24	11	18
Poor	8	4	3	5
	(of these 2 were worse than in the original view)		(2 high thoracic curves with short fusion, 1 lumbar curve, none worse)	

* In twenty-nine of these patients a total of 25 degrees or more correction was maintained.
** In twelve of these patients a total of 25 degrees or more correction was maintained.

together. Of 177 patients treated in the turnbuckle jacket, the results in 127 (72 per cent) were classed *good* to *excellent*. Of sixty-two patients treated in the localizer jacket, the results in forty-eight (77 per cent) were classed *good* to *excellent*.

LOSS OF CORRECTION

Any loss of correction must be explained. In this study, several causes were found which explained the loss of the initial correction. The first was poor selection of the fusion area, with the result that the fusion was either too long or too short. Of the two, making the fusion too short was the more serious error. If a too short fusion were not extended, loss of correction resulted; whereas, if it were extended, no further loss of correction occurred. In the group of patients in whom vertebral growth was complete at the time of fusion, no extension of the fusion was necessary. When growth was complete the loss of correction was small—being confined to the one or two joints in the curve which had not been fused. The loss was 33 per cent in the patients treated with turnbuckle jackets and none in fifty patients treated in the localizer casts. In the patients who were still growing there was an increasing loss of correction even after the removal of the cast until vertebral growth was complete. Therefore a fusion area which is too short should be extended in all patients in whom growth is not complete in order to prevent increasing deformity. For the same reason a pseudarthrosis in the growing child should be repaired (Table X).

The second cause for a loss of correction was an inefficient cast which did not hold the correction after spine fusion. This was termed *holding loss*. A comparison of the holding loss in patients treated in the turnbuckle jackets with that in patients treated in localizer casts showed that the holding loss was greater with the use of turnbuckle jackets. This loss usually occurred after the application of the supportive cast which was not usually corrective. In the localizer cast, on the other hand, each cast applied was corrective because of the pressure applied over the apex of the rib angulation (Table X).

A loss of 3 to 5 degrees may be within the limits of error in the method of measurement by the roentgen technique, but a loss of over 5 degrees indicates a real loss of correction. Of all the patients treated in the turnbuckle cast, there was in 59 per cent a loss of more than 5 degrees, whereas in only 32 per cent of the patients treated in the localizer was there a loss of over 5 degrees of this correction even though the patients treated in localizer casts were ambulatory two weeks after surgery, while those treated with the turnbuckle jacket were recumbent for three months after operation.

The third cause of loss of correction was either delayed fusion or pseudarthrosis. The holding loss was most marked in patients with either a short fusion area or pseudarthrosis.

TABLE X

POSTOPERATIVE LOSS WHILE WEARING CAST
(239 Curves)

	Slight or No Loss 0 to 5 degrees (*Per cent*)	Moderate or Severe Loss 5 degrees or more (*Per cent*)	Slight or No Loss 0 to 5 degrees (*Per cent*)	Moderate or Severe Loss 5 degrees or more (*Per cent*)
	67 Patients with Completed Growth at Time of Surgery			
	50 Turnbuckle Casts		17 Localizer Casts	
Short fusion not extended	67	33	100	0
Fusion delayed or pseudarthrosis suspected	10	90	44	56
Pseudarthrosis repaired	30	70	25	75
No pseudarthrosis, no short fusions	46	54	67	33
	172 Patients with Incomplete Growth at Time of Surgery			
	127 Turnbuckle Casts		45 Localizer Casts	
Short fusion not extended	56	44	75	25
Fusion delayed or pseudarthrosis suspected	8	92	100 (Only 3 Cases)	0
Pseudarthrosis repaired	12	88	43	57
Short fusion extended	33	67	50	50
No pseudarthrosis, no short fusions	64	36	90	10
	177 Turnbuckle Casts		62 Localizer Casts	
Average of all	41	59	68	32

The greatest losses occurred in the presence of pseudarthrosis. It is more difficult to maintain 30 than 10 degrees of correction. Therefore to hold the greater correction the fusion must be stronger. Pseudarthrosis is more common in patients in whom greater correction is obtained.

Pseudarthroses were explored and were repaired in 23 per cent of the patients treated in the turnbuckle jackets and in 17 per cent of the patients treated in the localizer cast. In three of the patients treated in the localizer cast, pseudarthrosis was thought to result from the use of a cast extending only to the axilla. Lateral motion is easily reflected into a thoracolumbar fusion area. Even in lumbar curves the cast should extend to a head or neck piece.

The incidence of pseudarthrosis in thirteen patients with metabolic and poliomyelitic scoliosis when extra bone from the tibia was added to the fusion area was 15 per cent. The series is too small to be significant, but it seems reasonable to assume that extra autogenous bone, added to that laid down in a well done Hibbs fusion is desirable.

CAUSES OF PSEUDARTHROSIS

Pseudarthroses proved by exploration were analyzed with respect to the severity and the location of the curvature (Table XI-A). The incidence of pseudarthrosis was greater in patients with the more severe deformities. Pseudarthrosis was also more common in the thoracolumbar and lumbar regions where the spine is more flexible. Both the severity and the location of the curve may be considered as variables which influence the stress on the graft.

TABLE XI-A

REPAIR OF PSEUDARTHROSIS

		Turnbuckle Cast (*Per cent*)	Localizer Cast (*Per cent*)
Curvature	Thoracic	13	10
	Thoracolumbar	33	30
Etiology	Metabolic	20	14
	Poliomyelitic	36	26
Severity of Curve	40 degrees or less	15	12
	Over 40 degrees	27	21
Repair of pseudarthrosis	(Greater percentage of pseudarthrosis in: thoracolumbar curves, curves over 40 degrees, and poliomyelitic scoliosis)	23	17
Age at surgery	Under fourteen	30	12
	Fourteen and over	18	27

The incidence of pseudarthrosis was greater in scoliosis due to poliomyelitis (Table XI-B).

Among the patients treated in the localizer cast, there appeared to be a greater incidence of pseudarthrosis in older patients in whom growth had been completed. Since the average age for the completion of vertebral growth is about fourteen years, those patients who were under fourteen years old were compared with those over fourteen years (Table XI-A). There is as yet no explanation for the differences observed.

LOSS OF CORRECTION IN RELATION TO COMPLETED VERTEBRAL GROWTH

In those patients in whom vertebral growth had been completed but in whom fusion was inadequate as to length or strength, the postoperative loss of correction appeared while they were still in the cast or soon after the removal of the cast. After this initial loss of correction there was no further loss and none of the curves in these patients became more severe than they were as seen in the original roentgenograms made with the patient standing. If the loss of correction were mild and the patient did not have pain, the pseudarthrosis was considered silent and was not repaired. On the other hand, if there was pain the loss of correction was recovered and the pseudarthrosis was repaired.

In those patients in whom vertebral growth had not been completed at the time of

TABLE XI-B

INCIDENCE OF PSEUDARTHROSIS

	Metabolic (*No. of Cases*)	Poliomyelitic (*No. of Cases*)	Total (*No. of Cases*)	Per cent
Total no. of cases of scoliosis (Ratio of male to female: 2:3)				
Female	132	37	169	70
Male	35	38	73	30
Total	167	75	242	100
Pseudarthrosis repair (Ratio of male to female: 2:6)				
Female	27 (20%)	12 (32%)	39 (23%)	72
Male	4 (11%)	11 (29%)	15 (21%)	28
Total	31 (19%)	23 (31%)	54 (22%)	100

removal of the cast and in whom fusion was inadequate as to length and strength, there occurred not only an initial loss of correction either in the cast or upon its removal but also a progressive loss which continued until vertebral growth had been completed. If this surgical error were not corrected and if there were sufficient vertebral growth remaining, the deformity would increase beyond that seen in the original roentgenogram made with the patient standing. In our series, there were two patients with pseudarthrosis who would not accept repair; their deformities increased beyond that seen in the original roentgenogram made with the patient standing. With completion of vertebral growth, the deformities became static. Early recognition of a pseudarthrosis or of a too short fusion and prompt repair of the pseudarthrosis or extension of the short fusion area will prevent loss of correction. The average loss of correction after secondary procedures was 8 to 10 degrees.

DISABILITY FOLLOWING SPINE FUSION

Will the fused spine withstand injury? Silent pseudarthrosis in an adult may become painful following an injury or excessive stress. In an automobile injury one patient had a fracture of a spinous process below the fusion area, but there was no damage to the fused spine. After the removal of the cast, a twelve-year-old child sustained a fracture of the fusion mass in a severe fall. The fracture healed spontaneously after immobilization for eight months. A man of twenty-one had a severe motorcycle accident ten years following removal of his cast. A roentgenogram showed a fracture through the fusion mass in an area where the fusion was considered to have been delayed. He had had no pain in his back until the accident occurred.

Recently a thirty-three-year-old patient was examined twenty-five years after the correction and fusion at the age of eight years at the New York Orthopaedic Hospital. His original curve measured 80 degrees. It had been corrected to 30 degrees, but there had been a loss of correction below the fusion area, which was too short, amounting to 15 degrees, leaving a total correction of 35 degrees. The fusion extended from the third thoracic to the third lumbar vertebra. This man had engaged in athletics, had run the 100-yard dash in ten seconds, and had played end on his high-school football team.

CONCLUSIONS

Increasing deformity in scoliosis can be prevented by spine fusion. Since prevention is easier than correction, mild curves should be considered for treatment. Forcible correction of the scoliotic deformity is possible by the combination of parallel traction and lateral bending in the turnbuckle jacket with anteroposterior hinges or by the same forces with the addition of localized posterolateral pressure on the apex of the rib angulation in the localizer cast.

Any loss of correction taking place in a cast or following its removal must be explained. The common causes of loss of correction are an inefficient postoperative cast, errors in the selection of fusion area, or a pseudarthrosis in the fusion area. Early recognition and repair of pseudarthrosis or extension of a fusion area which is too short prevent further loss of correction and increasing deformity in those patients in whom vertebral growth is not yet complete.

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The Pathogenesis and Treatment of Idiopathic Scoliosis

A Preliminary Report *

BY ADAM GRUCA, M.D., WARSAW, POLAND

The results of surgical treatment of idiopathic scoliosis are known. There is no method which corrects scoliosis in a child or adolescent or which even prevents its progress without extensive fusion and long immobilization of the spine. All other efforts directed to inhibit the growth of the vertebral bodies on the convex side of the curve have failed. In the adolescent and the adult, the curve may be partially corrected by conservative measures such as the use of the Risser jacket or the Milwaukee brace, by lengthening the concave side of the primary curve[1-8], or by wedge excision of the vertebral bodies[3,11] with subsequent fusion of the spine.

My experience is based on 172 patients operated upon during the last twelve years; a considerable number of other cases could not be recorded because the patients were operated upon prior to and during the last war. In adults and in adolescents, after partial lengthening of the concave side of the primary curve by conservative measures, the spine was fused with the use of ribs resected from the posterior prominence. As we do not regard fusion as a physiological procedure, thirty-nine of the postwar patients were children and were operated on by the dynamic bone-bridge technique[5] (Fig. 1). In the past year fifteen of these patients were re-examined to determine the results. These results were uniformly failures. The patients were from five to sixteen years old, the average age was twelve years, and the follow-up period was from one to twelve years, the average period being seven years. In patients with scoliosis of the first degree the curvature had increased on an average of 139 per cent. In those with scoliosis of the second degree, the curve had increased 74 per cent, and in those with third-degree scoliosis, the increase was 20 per cent. In the latter group, the average age at the time of operation was sixteen years.

We learned from these observations that no passive element such as bone or ligament can withstand the distorting factor in idiopathic scoliosis during the growth period of the patient and that this distorting factor could only be muscle imbalance. The existence of muscle imbalance in this condition was suspected by Andry more than two hundred years ago and more recently by Lombard, and probably by many others, but, as far as I know, never was proved. To obtain information about eighty-six cases of scoliosis in different stages of development in patients of different ages and in twelve controls, six normal children and six normal adults, the chronaxia of the muscles of the trunk was thoroughly studied[14]. It was found that the chronaxia of the trunk muscles was never identical on both sides of the primary curve in scoliosis and that there are two types of muscle changes in scoliosis. The primary muscle change is weakening on the convex side of the primary curve, due to some unknown cause. The secondary change, which may be reversible, is due to stretching and degeneration of muscles on the convex side in consequence of primary hyperactivity caused perhaps by reflex spasm of the muscles of the concave side, leading in time to their degeneration, especially the short interspinales, and finally to fibrosis.

The details of chronaximetric findings depend upon the duration and the stage of the scoliosis. The changes mentioned, of various degree and type, were also found in the common mass of the long spinal muscles as well as in the muscles of the scapula and

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 30, 1957.

of the arm and, in some cases, in the obliquus externus and internus abdominis muscles and in the quadratus lumborum.

To study the mechanics of the trunk muscles and to disclose their role in lateral bending and rotation of the spine, a mobile anatomical model was built with muscles represented by rubber bands. It was found anatomically [10] that segmental elimination or increased tension segmentally of spinal muscles (sacrospinalis and iliocostalis groups) and of the intercostales, leads to lateral curvature and torsion of the spinal column with the convexity toward the weakened muscles. This curvature, however, was limited to the dystonic segments in the upper portion of the thoracic spine, the lateral deviation extending caudad beyond the limits of the muscle imbalance. The muscles of the scapula and of the arm have no distinct influence on the production of deviation of the spine. The imbalance of the obliquus externus and internus abdominis muscles and of the quadratus lumborum leads to lateral shifting of the trunk and increases the rotation.

These investigations, as well as histological changes in the muscles of the spine in scoliosis [4], seem to support the view that idiopathic scoliosis is due to muscle imbalance at the level of the primary spinal curve or, somewhat above, in the upper portion of the thoracic spine.

This muscle imbalance, which may result from asymmetrical, congenital, or inherited abnormalities of innervation of the individual segments of the spinal muscles analagous to those, is accepted as the basis of congenital club-foot or pes cavus. Muscle imbalance may also result from the asymmetrical spasticity of cerebral palsy and from reflex spasm of the spinal muscles induced by inflammatory

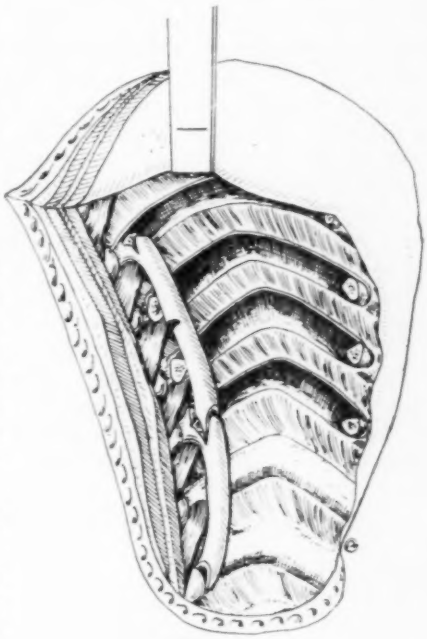

FIG. 1

Fig. 1: Illustration showing the dynamic bone-bridge technique. Ribs resected from the rib prominence unite the transverse processes of the terminal vertebrae.

Figs. 2-A and 2-B: Drawings show the strengthening of the long spinal muscles by the rhomboideus major. The mid-portion of the rhomboideus major is detached from the scapula and mobilized by blunt dissection toward the spine and fixed to the distal terminal vertebrae of the curvature.

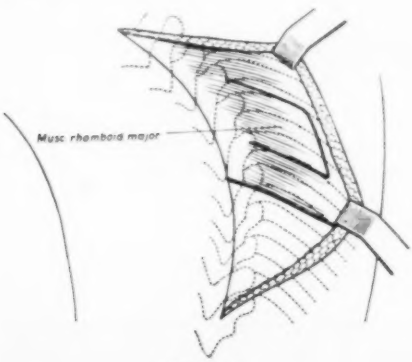

FIG. 2-A

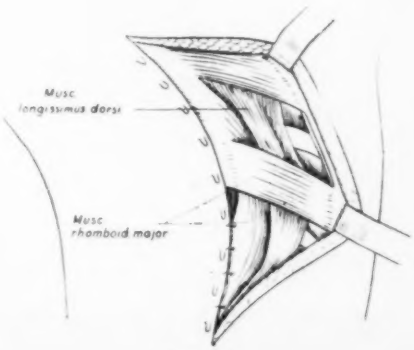

FIG. 2-B

lesions within the epiphyseal plates of the vertebral bodies or in the vicinity of the vertebrae (sympathetic ganglia, lymph tracts) within the muscles, lungs, or mediastinal organs.

Thus, idiopathic scoliosis seems to be a dynamic deformity which is functional at the beginning. The healthy muscles of the convex side try to rebalance the distorting action of the hyperactive muscles of the concave side and, in some cases, may stop the progress of the deformity. In other cases, when the deformity has increased, the distorting action of gravity is added and, with the passage of time, the functional scoliosis becomes structural until stabilization in the pathological state becomes possible.

With these facts in mind, the aim of treatment should be to restore the muscle balance as soon as possible if conservative treatment fails to straighten the spine. The muscle equilibration may be realized in different ways. The primarily and definitively damaged muscles of the convex side, as seen in persons who have had poliomyelitis or neurofibromatosis, may be replaced or strengthened by transplantation of muscles of the scapula or of the arm, if these muscles are not also seriously affected. The longissimus dorsi muscle may be replaced in the upper portion of the thoracic spine by the rhomboideus major muscle (Figs. 2-A and 2-B) or by the upper part of the trapezius muscle (Figs. 3-A and 3-B) and in the lower portion of the thoracic spine distorted by scoliosis by the lower part of the trapezius muscle (Figs. 4-A, 4-B, and 4-C) or by the upper part of the latissimus dorsi muscle (Fig. 5). The hypertonic muscles of the concave side, as in patients with cerebral palsy, should be weakened by section or denervation.

The secondarily and temporarily weakened muscles of the convex side may be strengthened by the introduction of artificial muscles. In adequately qualified patients, we were able to restore full functional recovery of these muscles as proved by chronaximetry [14] and by regression of the scoliosis. When our planning or technique was inadequate, we observed either no change or an aggravation of the imbalance (Table I).

The technique of alloplasty (Figs. 7-A and 7-B) of muscles should not prove difficult. A flattened spiral spring of adequate power, made of stainless steel, is fastened upon the transverse processes of the vertebrae at each end of the convex side of the primary curve. If the spring is placed under the correct amount of tension, the curve will be reduced immediately. Further progressive correction paralleling the growth of the patient was observed in some cases.

The calculation of the power and stretching of the spring is a more difficult and

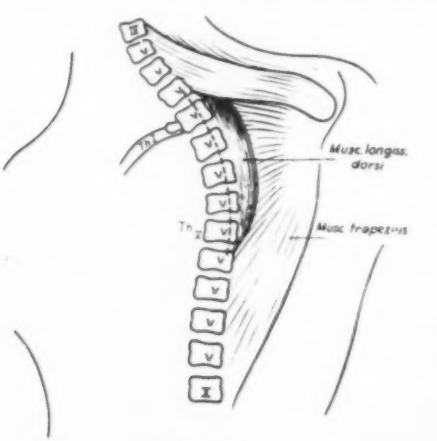

FIG. 3-A

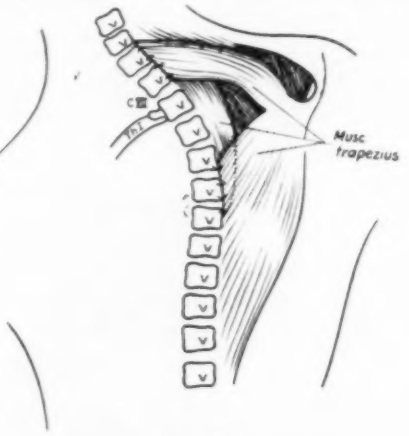

FIG. 3-B

Figs. 3-A and 3-B: Drawings show the method of replacement of the dystonic longissimus dorsi muscle by the mid-portion of the trapezius muscle in a patient with scoliosis in the upper portion of the thoracic spine. A tonguelike portion of the trapezius muscle, detached from the scapula and mobilized toward the spine, is fixed to the spinous processes of the vertebrae at the distal end of the curve.

delicate question in which further investigations are indicated. To balance the spine, the spring should cover the deficit of the muscle power at the level of the primary curve. To calculate it, one should know the absolute power of the long spinal muscles at this level and the degree of the dystonia. Some information about the muscle power may be obtained from anatomical tables (Table II), but there is no method known which will give precise information about the degree of the dystonia of muscles. Therefore, the tension of the springs was calculated empirically. The clinical observations led to the conclusion that the tension of the spring, expressed in kilograms, must be equal to the gravity of the parts of the body superimposed at the apex of the primary curve with a 100 per cent to 150 per cent reserve being provided for the future growth of the spine. In a normal adult with a body weight of sixty kilograms, the pressure upon the sixth thoracic vertebra was calculated by the anatomist to be sixteen and one-half kilograms (Table III). In a child weighing twenty kilograms, the pressure would be 5.5 kilograms. Therefore, in this case, a spring must be used which when stretched to 150 per cent of its length exerts a pull of 16.5 kilograms, but it should be inserted stretched to 50 per cent of its length, thus exerting a

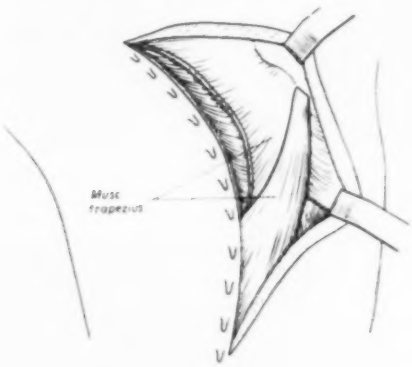

FIG. 4-A

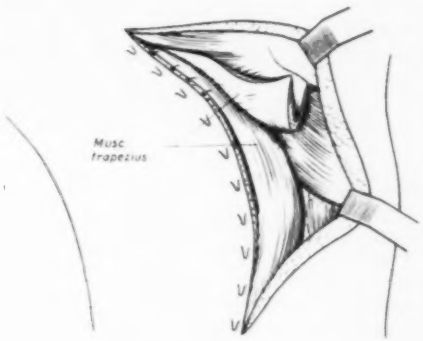

FIG. 4-B

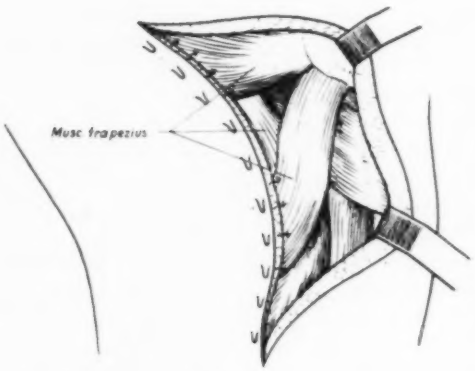

FIG. 4-C

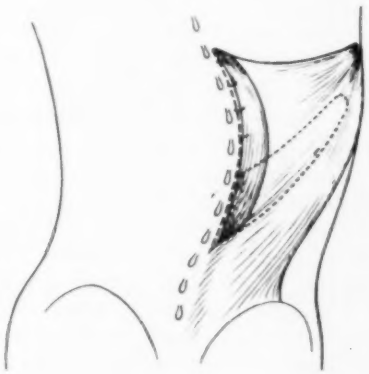

FIG. 5

Figs. 4-A, 4-B, and 4-C: Drawings show the replacement of the inactive long spinal muscles by the trapezius muscle in a patient with scoliosis in the lower portion of the thoracic spine. The distal portion of the trapezius muscle, detached from the scapula, is sutured to the vertebrae at the proximal end of the curve.

Fig. 5: The technique of strengthening of the long spinal muscles by the latissimus dorsi in a patient with scoliosis in the thoracolumbar spine is shown in drawing. Tonguelike mid-portion of the latissimus dorsi muscle, mobilized by blunt dissection toward the spine, is sutured to the vertebrae at the proximal end of the primary curve.

TABLE I

CHRONAXIMETRIC VALUES IN TEN PATIENTS WITH PRIMARY RIGHT THORACIC AND SECONDARY LEFT LUMBAR IDIOPATHIC SCOLIOSIS BEFORE AND AFTER MUSCLE ALLOPLASTY *

Sacrospinalis Muscle	Position for Examination	Type of Scoliosis	Average Chronaximetric Values † Before Muscle Alloplasty (*Milliseconds*)	After Muscle Alloplasty (*Milliseconds*)
Seventh thoracic segment	Recumbent	Primary (concave)	0.16 (0.12–0.36)	0.26 (0.15–0.35)
Seventh thoracic segment	Recumbent	Primary (convex)	1.42 (0.2–10.0)	0.27 (0.15–0.35)
Ninth thoracic segment	Recumbent	Primary (convex)	0.24 (0.14–0.35)	0.27 (0.13–0.35)
Ninth thoracic segment	Recumbent	Secondary (convex)	0.13 (0.07–0.18)	0.27 (0.18–0.32)
First lumbar segment	Recumbent	Secondary (convex)	0.16 (0.05–0.25)	0.26 (0.2–0.35)
First lumbar segment	Recumbent	Secondary (concave)	0.25 (0.24–0.26)	0.26 (0.15–0.35)
Seventh thoracic segment	Standing	Primary (concave)	0.25 (0.2–0.3)	0.27 (0.24–0.37)
Seventh thoracic segment	Standing	Primary (convex)	0.48 (0.25–0.7)	0.25 (0.15–0.4)
Ninth thoracic segment	Standing	Secondary (convex)	0.6 (0.45–0.85)	0.23 (0.1–0.36)
Ninth thoracic segment	Standing	Primary (convex)	0.4 (0.25–0.6)	0.26 (0.15–0.35)
First lumbar segment	Standing	Secondary (convex)	0.59 (0.35–1.0)	0.26 (0.18–0.35)
First lumbar segment	Standing	Secondary (concave)	0.25 (0.15–0.36)	0.24 (0.15–0.32)

* Before muscle alloplasty, the higher chronaximetric values obtained from patients in the recumbent position at the convex side of the curve suggest lowered muscle tension. Numbers in parentheses suggest overloading of muscles when values were obtained from patients in the standing position. In patients in the recumbent position after operation, the chronaxia is equal or shows the tendency to equilibration. With patients in the standing position, there are no symptoms of muscle overloading.

† In children, the values are symmetrical on both sides from 0.08 to 0.36, an average of 0.15.

temporary pull of 5.5 kilograms. The age of the patient must be taken into account as well. Greater tension and a smaller reserve must be allowed for pre-adolescent children than for those in the first decade of life. (Fifty per cent is added to the value calculated for scoliosis of the first degree in patients with scoliosis of the second degree, and in those with scoliosis of the third degree, 100 per cent is added.)

In our series we used springs made of stainless-steel spring wire, *Dentaurum Pforzheim*, 1.2 to 1.5 millimeters thick with a maximal pulling power of ten to fifteen kilograms stretched for 30 to 50 per cent of their length to exert pull from three to 4.5 kilograms. If more than five kilograms pulling power were indicated, two springs were overlapped on different transverse processes to avoid excessive pressure of the wire upon the bone.

Table IV shows the results of the muscle springplasty. In the first series of eighteen patients with scoliosis of the first degree (rigid angulation of the primary curve of less than 30 degrees) observed up to two years, there was a correction of from 9.5 to 100 per cent, an average of 50 per cent (Figs. 8-A and 8-B). The youngest patient in this series was two and one-half years old; the eldest was seventeen years. The relatively low average correction is due to poor correction in the earlier cases in which rubber cords or weak springs were used. In fifteen patients in this series no postoperative physical therapy was done. The children remained in bed for three weeks and then were allowed to walk

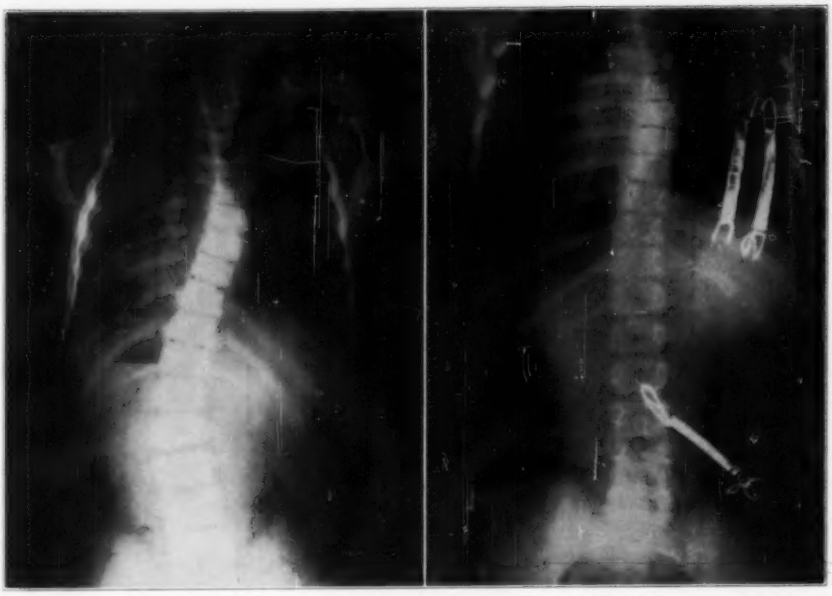

FIG. 6-A

Roentgenogram made before muscle alloplasty.

FIG. 6-B

Roentgenogram made after the operation

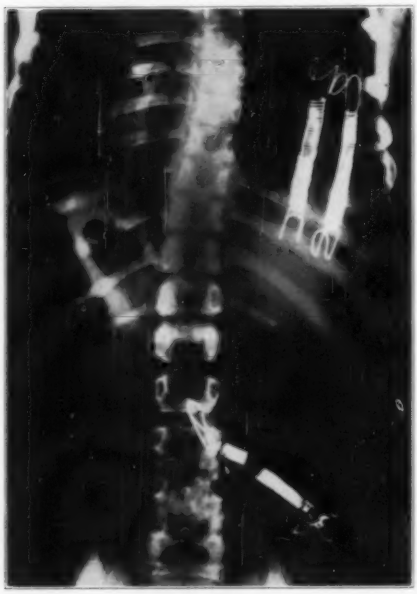

FIG. 6-C

The scoliosis remains regressed as seen in roentgenogram made some months after fracture of the lower spring.

Figs. 6-A, 6-B, and 6-C: Roentgenograms showing progress in a patient with thoracolumbar scoliosis of the first degree.

freely without any external support. In the new series, systematic routine physical therapy was started about ten days after the operation with the patients in recumbent position.

We regard this procedure to be indicated in (1) all children, regardless of age, with scoliosis of the first degree which has increased despite properly conducted conservative treatment; and (2) in children with cervicothoracic scoliosis even without preliminary conservative treatment.

Lateral shifting of the thorax due to imbalance of the anterolateral abdominal muscles must be eventually corrected by a second operation. Good correction was obtained either by fascial transplant or by dermodesis uniting the iliac crest of the concave side of the thorax with the ribs of the convex side by the Lowman method. Transplantation either of the tensor fasciae latae (Fig. 9), of the lower part of the serratus anterior, trapezius (Fig. 10), or latissimus dorsi (Fig. 11) tends to correct the imbalance of the anterolateral abdominal muscles. The dystonic quadratus lumborum may be successfully strengthened by lateral transposition of the distal insertion of the sacrospinalis (Fig. 12). The results of these

TABLE II

POWER OF THE LONG SPINAL MUSCLES MEASURED AFTER TRANSVERSE SECTIONING AT THE LEVEL OF THE INTERCOSTAL SPACES

Rib	Absolute Power (*Kilograms*)	Lever Arm (*Centimeters*)
Longissimus dorsi		
First	7	3
Second	8	3
Third	9	3
Fourth	10	3
Fifth	11	3
Sixth	13	3
Seventh	18	3
Eighth	23	3
Ninth	28	3
Tenth	38	3
Eleventh	53	3
Twelfth	73	3
Iliocostalis		
First	7	4.2
Second	6.4	4.7
Third	5.8	5.4
Fourth	5.0	5.8
Fifth	4.0	6.2
Sixth	4.0	6.7
Seventh	5.0	6.7
Eighth	6.0	7.0
Ninth	9.0	7.2
Tenth	14.0	7.0
Eleventh	24.0	6.7
Twelfth	33.0	6.4
Spinalis		
First through twelfth	4.4	(spinous processes)
Transversospinales		
First through twelfth	11.3	
Extensor component	9.75	
Rotational component	1.55	

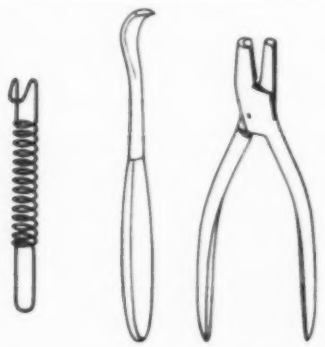

FIG. 7-A

Fig. 7-A: Drawing shows the spiral spring and instruments used in muscle alloplasty. The curved rasp is to prepare the bed on the transverse process; the clamp is for bending the springs.

Fig. 7-B: The spring hooked on the transverse processes of the vertebrae at each end of the curve is shown in drawing.

FIG. 7-B

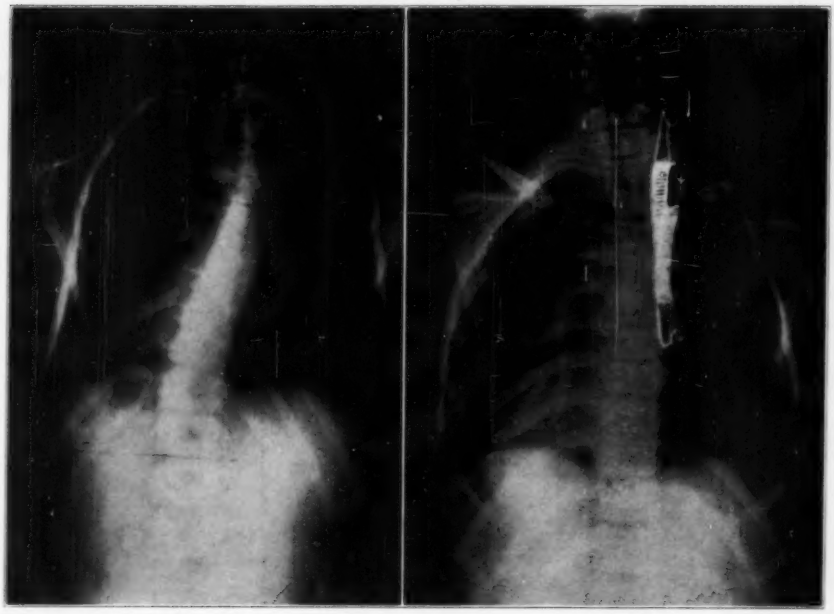

FIG. 8-A FIG. 8-B

Figs. 8-A and 8-B: Roentgenograms made of a patient with scoliosis of the first degree before and after muscle alloplasty.

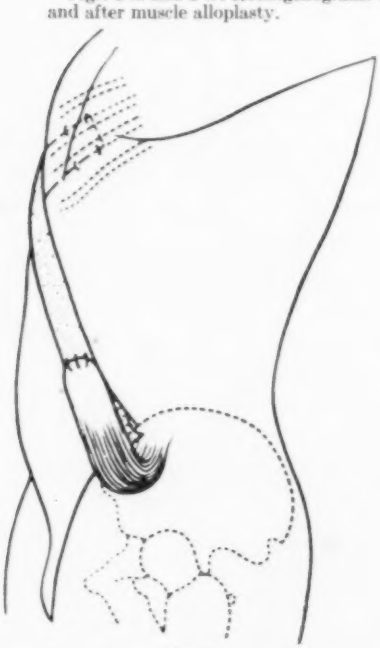

FIG. 9

Fig. 9: Drawing illustrates fasciodesis activated by tensor fasciae latae. The distal end of the tensor fasciae latae of the concave side of the thorax is sutured on a fascial or dermal band.

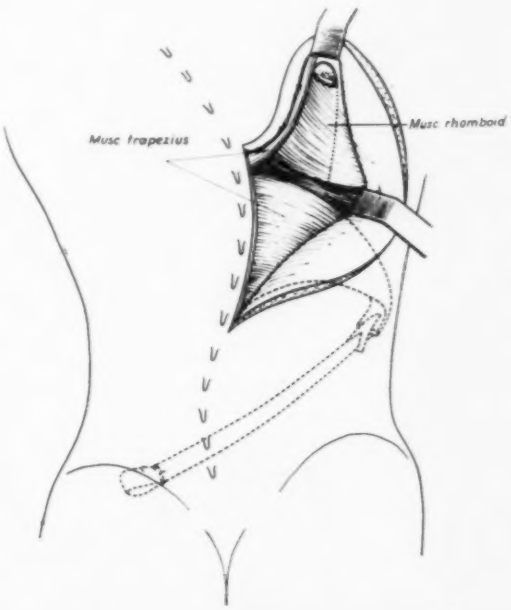

FIG. 10

Fig. 10: Drawing shows dermodesis activated by trapezius muscle, detached from the scapula and mobilized by blunt dissection toward the spine, prolongated by dermal band and fixed intra-osseously to the iliac crest of the concave side of the thorax.

TABLE III

APPROXIMATE PRESSURE ON THE THORACIC AND LUMBAR VERTEBRAE EXERTED BY THE SUPERIMPOSED BODY WEIGHTS IN AN ADULT WEIGHING SIXTY KILOGRAMS

Vertebra	Pressure (*Grams*)
First thoracic	5.770
Second thoracic	9.080
Third thoracic	12.710
Fourth thoracic	13.470
Fifth thoracic	15.015
Sixth thoracic	16.555
Seventh thoracic	17.825
Eighth thoracic	18.975
Ninth thoracic	20.275
Tenth thoracic	21.610
Eleventh thoracic	22.850
Twelfth thoracic	23.915
First lumbar	24.875
Second lumbar	25.855
Third lumbar	26.755
Fourth lumbar	27.615
Fifth lumbar	28.515

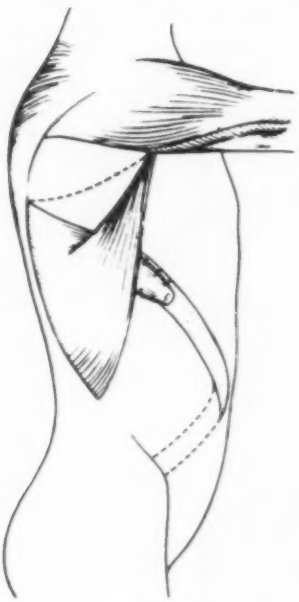

FIG. 11

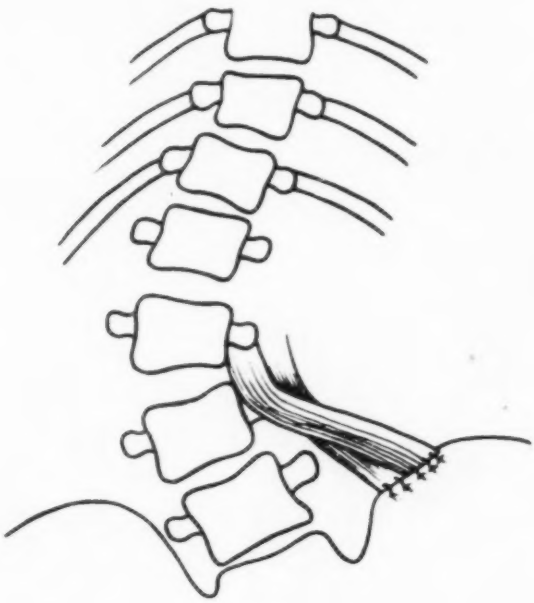

FIG. 12

Fig. 11: Drawing of fasciodesis activated by latissimus dorsi muscle. The proximal half of the latissimus dorsi muscle, detached from the humerus and mobilized by blunt dissection toward the spine, is sutured on a fascial or dermal band uniting the ribs of the convex side of the thorax with the iliac crest of the concave side.

Fig. 12: Drawing shows the distal insertions of the longissimus dorsi and iliocostalis muscles detached from the iliac crest and sacrum, mobilized to the level of the third lumbar vertebra, and fixed subperiosteally to the iliac crest at the level of the posterior axillary line.

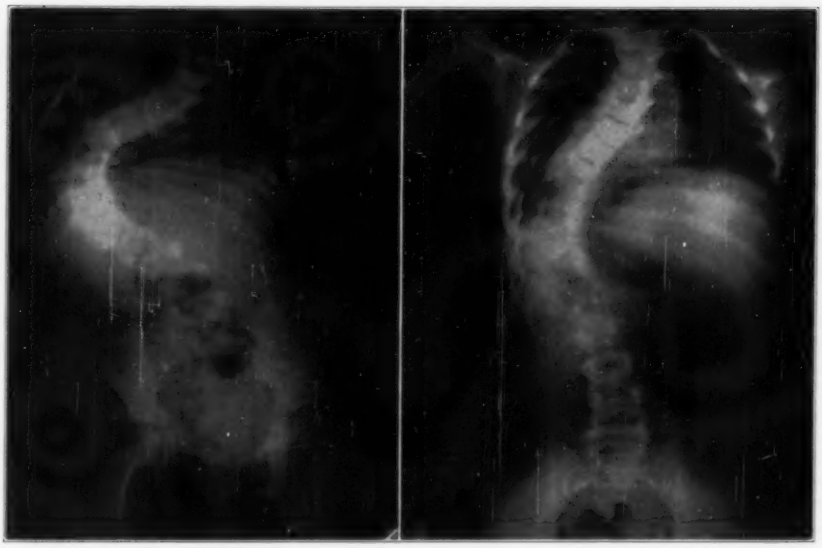

FIG. 13-A FIG. 13-B

FIG. 14-A FIG. 14-B

Figs. 13-A and 13-B: Roentgenograms showing scoliosis of the third degree before and after operation consisting in muscle alloplasty by rubber cords and fasciodesis activated by the serratus anterior muscle.

Figs. 14-A and 14-B: Photographs of patient before and after treatment by alloplasty and activated fasciodesis.

operations are demonstrated in Figures 13-A through 14-B.

In patients with scoliosis of the second degree with rigid angulation of from 30 to 60 degrees the muscle springplasty provided an average correction of only 47 per cent of the angulation (Figs. 15-A and 15-B). The procedure already outlined appeared insufficient to counteract the action of gravity or the contractures of soft tissues on the concave side of the curve and to reduce the deformity more substantially. Thus, in scoliosis of the second degree, the springplasty is not indicated until the angulation is reduced to less than 30 degrees. This may be achieved either by conservative measures such as the turnbuckle jacket or by surgical division of contracted soft tissues on the concave side of the primary curve by the spine-liberation method described by Mayer. The immediate correction of the angulation is secured by a screw-spring device or distracter (Fig. 16), which is placed between the transverse processes of the vertebrae at each end of the concave side of the curve. The aim of this device is to balance the distorting action of gravity and to gradually reduce the angulation. For this purpose the expanding power of the spring must be adapted to the weight of the superimposed parts of the body (Table III). The technique of the operation is shown in Figure 17, the results obtained in sixteen cases by the first step of this procedure

TABLE IV

RESULTS OF MUSCLE SPRINGPLASTY IN TWENTY-SIX CASES

	No. of Cases	Correction Obtained (*Per Cent*)	Average Correction (*Per Cent*)
First-degree scoliosis (fixed angulation less than 30 degrees)	18	9.5–100	50
Second-degree scoliosis (fixed angulation 30 to 60 degrees)	6	28 – 62	47.2
Third-degree scoliosis (fixed angulation greater than 60 degrees)	2	10 – 34.6	24.8

TABLE V

RESULTS OF SPINE LIBERATION AND DISTRACTION IN SIXTEEN CASES

	No. of Cases	Correction Obtained (*Per Cent*)	Average Correction (*Per Cent*)
Second-degree scoliosis	2	24.5–55	40
Third-degree scoliosis	14	20 –58.7	35

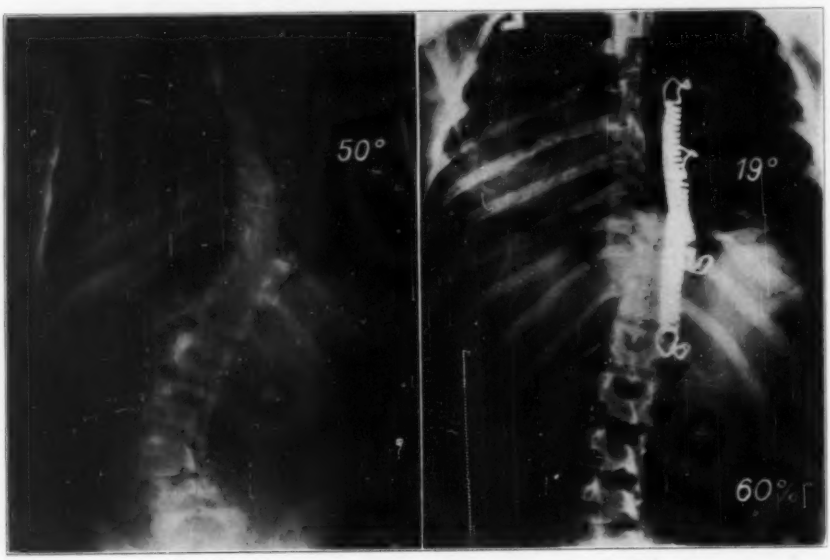

FIG. 15-A FIG. 15-B

Figs. 15-A and 15-B: Roentgenograms showing scoliosis of the second degree before and after springplasty.

in Table V and in Figures 18-A through 19-B. The average correction obtained in scoliosis of the second degree was 40 per cent, measured with the patient in the recumbent position.

Some weeks later, when the angulation is reduced to less than 30 degrees, muscle alloplasty is performed on the convex side of the spine, and conversely, if springplasty were performed in the first operation, liberation and distraction will be done some weeks later. An example of the combined method is shown in Figures 20-A and 20-B. We regard

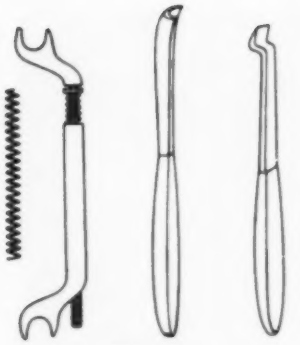

FIG. 16

Fig. 16: Drawing of instruments for spine liberation and distraction: *Left:* distracter; *center:* rasp for liberation of the transverse processes; *right:* bayonet-like rasp for sectioning of the articular capsule and ligamenta flava.

Fig. 17: Drawing shows distracter fixed between transverse processes of the vertebrae at each end of the curve.

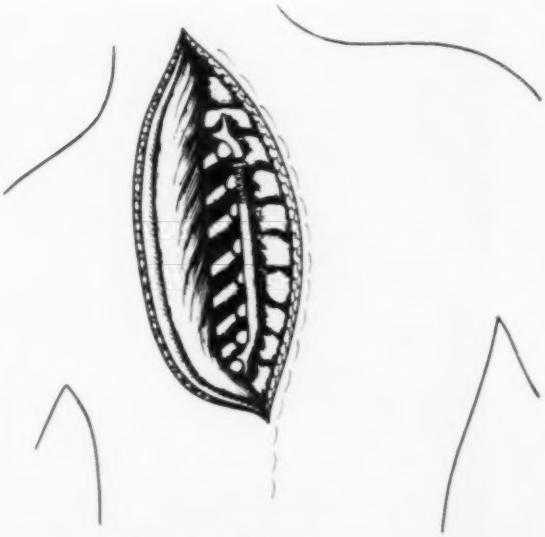

FIG. 17

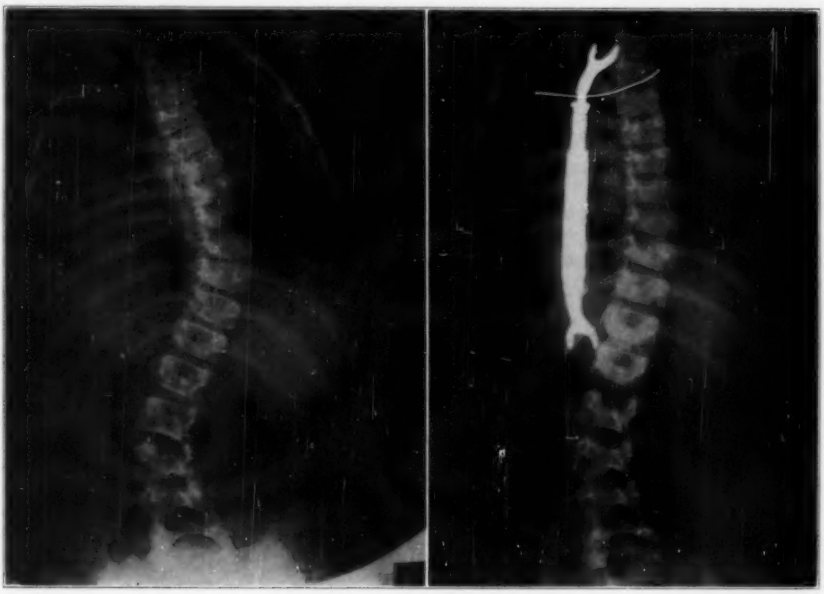

FIG. 18-A FIG. 18-B

Figs. 18-A and 18-B: Roentgenograms show thoracic scoliosis before and after spine liberation and distraction.

this combined treatment to be indicated for all patients with severe deformity, even children and adults in whom the deformity is not progressing.

In patients with scoliosis of the third degree, with a rigid angulation greater than 60 degrees, full correction cannot be achieved due to the overgrowth of bone on the convex side of the curve. The springplasty alone has given only 24.8 per cent correction, the spine

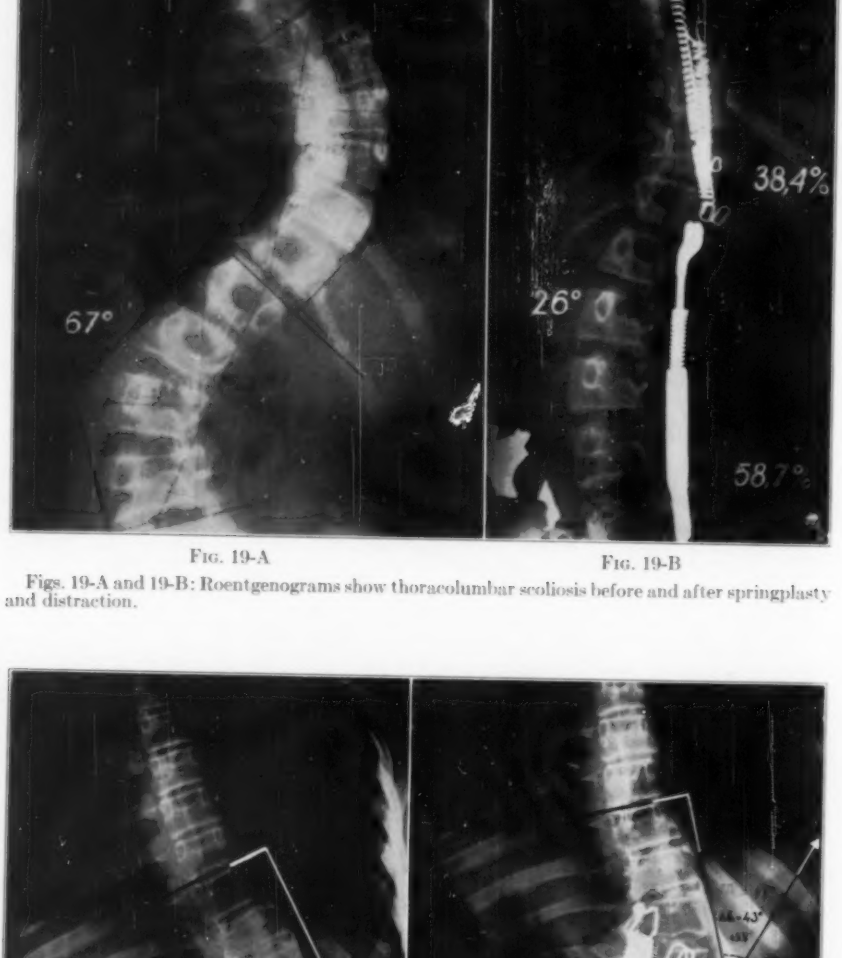

FIG. 19-A FIG. 19-B

Figs. 19-A and 19-B: Roentgenograms show thoracolumbar scoliosis before and after springplasty and distraction.

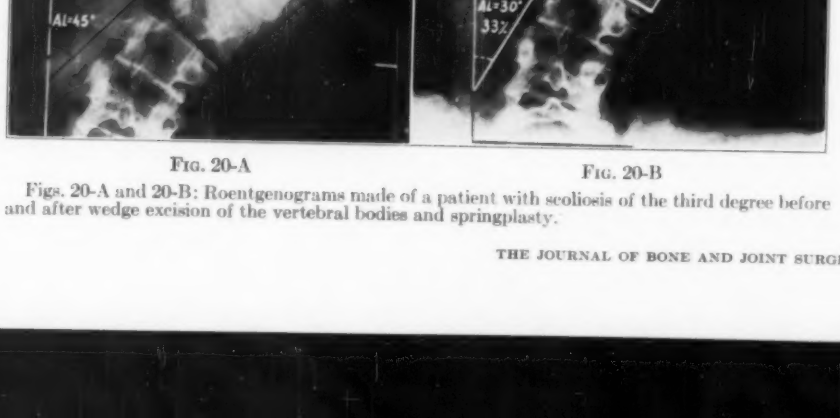

FIG. 20-A FIG. 20-B

Figs. 20-A and 20-B: Roentgenograms made of a patient with scoliosis of the third degree before and after wedge excision of the vertebral bodies and springplasty.

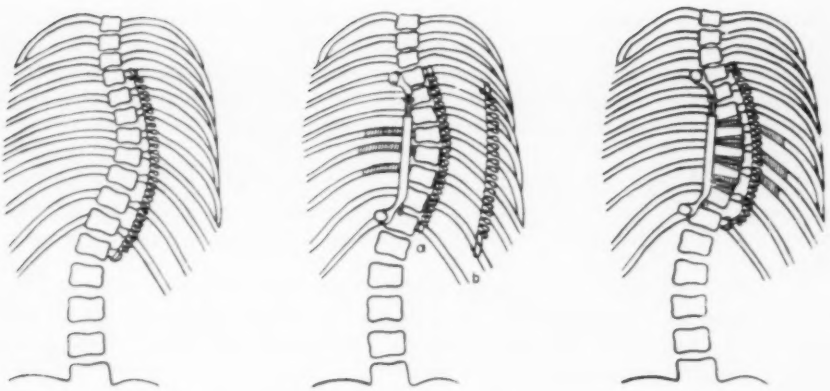

FIG. 21

Drawing shows the techniques used in thoracic curvature of the first, second, and third degree.

liberation and distraction 35 per cent correction. These patients also were treated by the two-step procedure. In the first operation on the concave side of the curve the liberation of the spine and the insertion of the spring-screw device were completed, followed some weeks later by the second operation on the convex side, consisting in excision of the articular vertebral processes, or wedge resection of the intervertebral discs or vertebral bodies through the posterolateral approach with insertion of pulling springs and eventual fusion of the primary curve. This combined procedure was done in twelve patients, most of whom are still under treatment and cannot be evaluated. In five patients with severe scoliosis of the third degree, correction from 22.5 per cent to 45 per cent was obtained. The techniques used in thoracic curvatures of various severity are shown in Figure 21.

In our approach to the problem of scoliosis there are still many questions that are unanswered. We have no precise method of calculating the degree of muscle imbalance or of calculating the exact power and tension of the springs to be applied. We do not know the future of the inserted springs or the solution of many other problems.

Nevertheless the results after a follow-up of two and one-half years in the fifty-five cases seem to indicate that by these simple and reversible means we are able to straighten scoliosis in its early stages and to obtain further correction parallel to the growth of the patient and at least stop the progress of the curvature in those with severe scoliosis.

SUMMARY

On the basis of chronaximetric, myomechanical, and histological examination of the long spinal muscles we assume that idiopathic scoliosis is due to muscle imbalance at the level of its primary curve. This dystonia of muscles may result from asymmetrical congenital, or sometimes inherited, segmental abnormalities of innervation of spinal muscles, or from reflex spasm induced by inflammatory lesions within the vertebral column or in its vicinity, in lungs, or in mediastinal organs.

The convexity of the angulation is always directed toward the weakened muscles. The muscles of the scapula and of the arm have no influence on the production of scoliosis. The imbalance of the anterolateral abdominal muscles leads to lateral shifting of the trunk.

Scoliosis may be cured or its progress prevented only by early restoration of muscle balance. For this purpose the definitively damaged muscles must be replaced by transplantation of healthy muscles of the scapula or the arm (the trapezius, rhomboidei, or latissimus dorsi). The hyperactive muscles should be weakened by section or denervation. The secondarily and temporarily weakened muscles must be strengthened by the intro-

duction of artificial muscles. This muscle alloplasty leads, in scoliosis of the first degree, to full regression of the angulation or at least to considerable improvement and stabilization. In scoliosis of the second degree springplasty should be performed after stretching of the angulation of less than 30 degrees by conservative measures or by the spine-liberation operation after Mayer's method with temporary application of the screw-spring device or distracter.

In scoliosis of the third degree after maximal correction of the angulation by conservative measures or by spine liberation and distraction, the excess bone of the laminae and of the vertebral bodies must be removed and pulling springs must be applied in the second operation.

The lateral shifting of the trunk due to dystonia of the obliquus externus and internus abdominis muscles may be successfully reduced by oblique fascial transplant after the method of Lowman, with the use of the latissimus dorsi, serratus anterior, trapezius, or tensor fasciae latae muscles.

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Compression in Arthrodesis

A Comparative Study of Methods of Fusion of the Knee in Ninety-Three Cases

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Thirty-seven operations with compression in arthrodesis of the knee have been performed by members of the Campbell Clinic since August 1948. Of these, follow-up is adequate for evaluation of results in thirty patients on whom thirty-one operations were performed. For a clinical comparison, sixty-three fusions by other methods, in sixty-one patients, were studied; these were drawn from our files of 1930 through 1950. Throughout the discussion, the term *union* denotes definite clinical and roentgenographic evidence of arthrodesis. The group treated by the so-called conventional methods will be considered first.

TABLE I

Conditions Necessitating Fusion

Conventional Arthrodesis

Condition	No. of Operations
1. Tuberculosis	22
2. Pyogenic arthritis	23*
3. Miscellaneous (16):	
Degenerative arthritis	6
Rheumatoid arthritis	4
Gonorrheal arthritis	2
Poliomyelitis with instability	2
Osteochondromatosis	1
Arthrogryposis	1
4. Charcot's joint	2
Total	63

* Twenty-one patients.

ARTHRODESIS WITHOUT COMPRESSION

Table I shows the diagnoses, and Table II shows the length of time required for union in the sixty-three fusions done by conventional methods.

This series designated *conventional arthrodesis* refers to all types of surgical fusions exclusive of the compression arthrodesis. Many of the operations were performed by removing the articular cartilage from the bones of the knee joint, resecting, and fitting the fresh cancellous surfaces together. Some procedures were supplemented by internal fixation with Steinmann pins, Knowles pins, Vitallium or stainless-steel screws, and others by cortical and patellar bone grafts. All patients were immobilized in plaster of Paris postoperatively.

Patients with Tuberculosis

Three of the twenty-two patients with tuberculosis had non-union when no internal

TABLE II

TIME REQUIRED FOR FUSION
Conventional Arthrodesis

Condition	No. of Operations	Average No. of Weeks In Plaster Spica	In Toe-to-Groin Plaster	Total
Tuberculosis	22	15.3	14.0	29.3
Pyogenic arthritis	23*	10.25	5.35	15.6
Miscellaneous (16):		10.8	6.3	17.1
Degenerative arthritis	6			
Rheumatoid arthritis	4			
Gonorrheal arthritis	2			
Poliomyelitis with instability	2			
Osteochondromatosis	1			
Arthrogryposis	1			
Charcot's joint	2			
Total	63			

* Twenty-one patients.

fixation was used, and two when crossed Knowles pins were used. One patient was not followed adequately. One in whom crossed Steinmann pins were used had sepsis which made amputation necessary, and is therefore not included in the subsequent statistics. There were twelve males and ten females. No significant difference between the sexes in the time

Figs. 1-A through 1-D: Roentgenograms of a thirty-eight-year-old woman, P.R., who had a positive Wassermann test and had progressive numbness and instability of the left knee for six years. On February 28, 1946, fusion of the knee with fixation by two Knowles pins and two cortical-bone grafts from the opposite tibia was done. She had been immobilized in a single spica cast for six months when the pins broke and the grafts disintegrated. The knee has remained ununited.

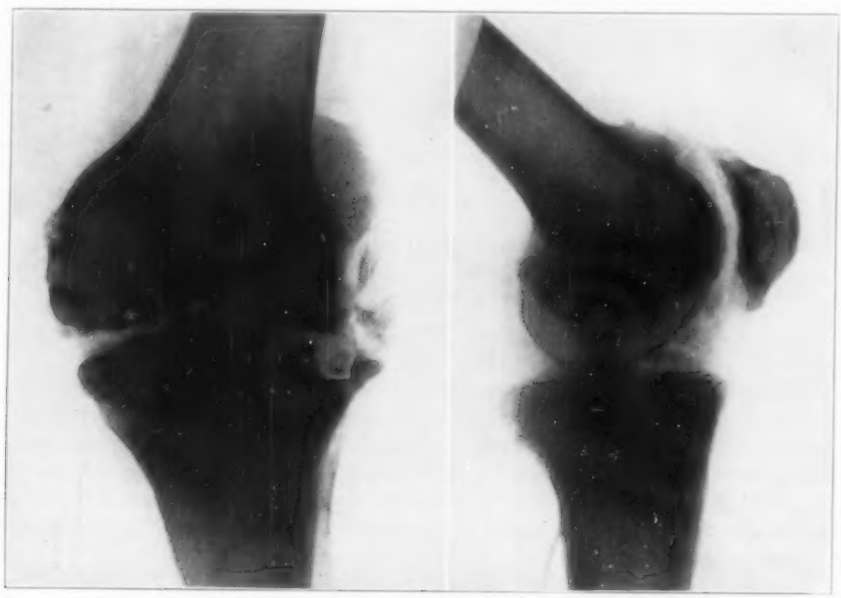

FIG. 1-A
January 16, 1946

FIG. 1-B
March 7, 1946

FIG. 1-C
April 12, 1946

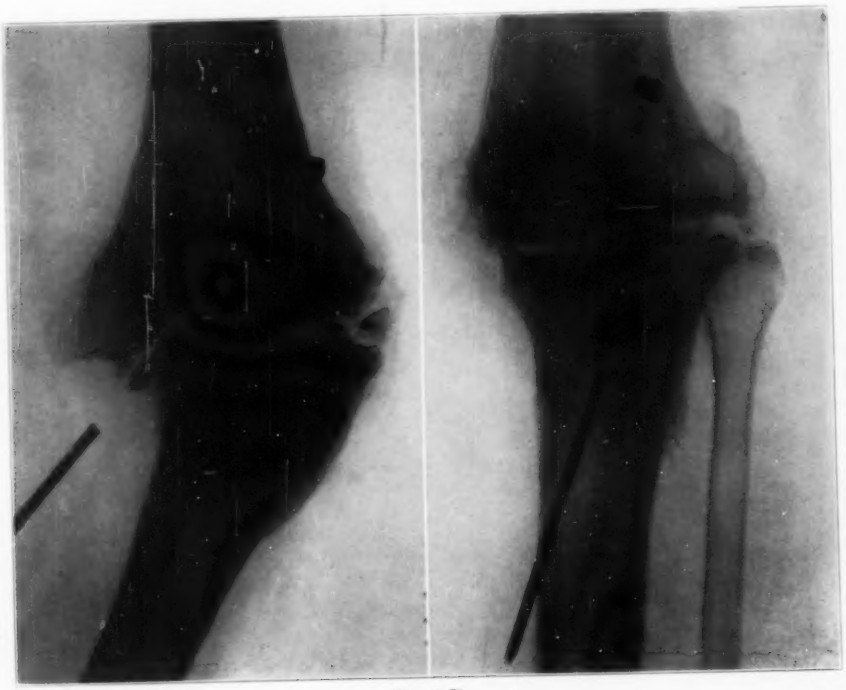

FIG. 1-D
April 6, 1949

required for union was noted. The ages of the patients at the time of operation ranged from six and one-half to sixty-eight years, the average age being thirty-six years and five months.

Plaster-spica fixation was employed for an average of 15.3 weeks followed for fourteen weeks by toe-to-groin plaster. The average total time required for union was 29.3 weeks. One patient required 156 weeks for union. If this case is omitted, average time for union with crossed Knowles pins is 23.0 weeks, which is probably a more representative figure than the 27.4 weeks' average time required by the eleven patients in whom crossed Knowles pins were used. Internal fixation with crossed Steinmann or Knowles pins was used in sixteen operations. These knees required an average of 11.3 weeks longer before union was complete than those in which no internal fixation was used.

Patients with Pyogenic Arthritis

Of the twenty-one patients with pyogenic arthritis, two had non-union and one was not adequately followed. Steinmann pins were used as internal fixation in one of the patients with non-union; no internal fixation was used in the other. Thirteen males had fifteen operations and eight females had eight operations. No significant difference in time of union in the two sexes was noted. The ages of the patients ranged from ten to fifty-nine years; the average age was 28.7 years. The majority of patients were under forty years of age. Spica fixation was used for an average of 10.25 weeks for the group, while the av-

Figs. 2-A and 2-B: L.J., a woman, twenty years of age, who had tuberculosis of the knee of eight years' duration, had a Bosworth-type fusion on July 30, 1946. One Smith-Petersen nail was used from the medial femoral to the lateral tibial condyle and the patella was fixed by one screw to the femur and one to the tibia. The leg was maintained in plaster of Paris for three months and a toe-to-groin leather brace was continued for an additional six months. These roentgenograms demonstrate how compression can occur with backing out of the Smith-Petersen nail allowing excellent contact of the bone surfaces and fusion.

FIG. 2-A
August 15, 1946

erage total time required for union was 15.6 weeks. Ambulation was begun, on the average, 10.5 weeks postoperatively. Internal fixation with crossed Steinmann pins, Knowles pins, or screws was used in seventeen operations. These knees required an average of 4.6 weeks longer before union was complete than those in which no internal fixation was used.

Patients with Miscellaneous Conditions

Union was obtained in all of these sixteen patients, of whom eight were men and eight were women. No significant difference between the sexes was noted in the time required for union. The ages of the patients ranged from thirteen to sixty-one years; the average age was 41.4 years. Spica fixation was used for an average of 10.8 weeks for the group, while the average total time required for union was 17.1 weeks. Ambulation was begun, on the average, 16.8 weeks postoperatively. Internal fixation with crossed Steinmann or Knowles pins was used in thirteen operations. The knees in this group required an average of 15.6 weeks before union was complete, as compared with the three in which no internal fixation was used, which required an average of 24.3 weeks.

Patients with Charcot's Joint

Two patients had Charcot's joint. One was a woman, thirty-eight years old, in whom crossed tibial grafts and crossed Knowles pins were used for internal fixation. The knee failed to fuse. The other was a twelve-year-old boy, for whom the postoperative follow-up was inadequate for evaluation.

Observations

It must be remembered that surgical techniques and the use of antibiotic therapy have made great strides since the patients recorded early in this series were operated upon. We have now learned that rigid internal fixation, which may hold the joint surfaces apart

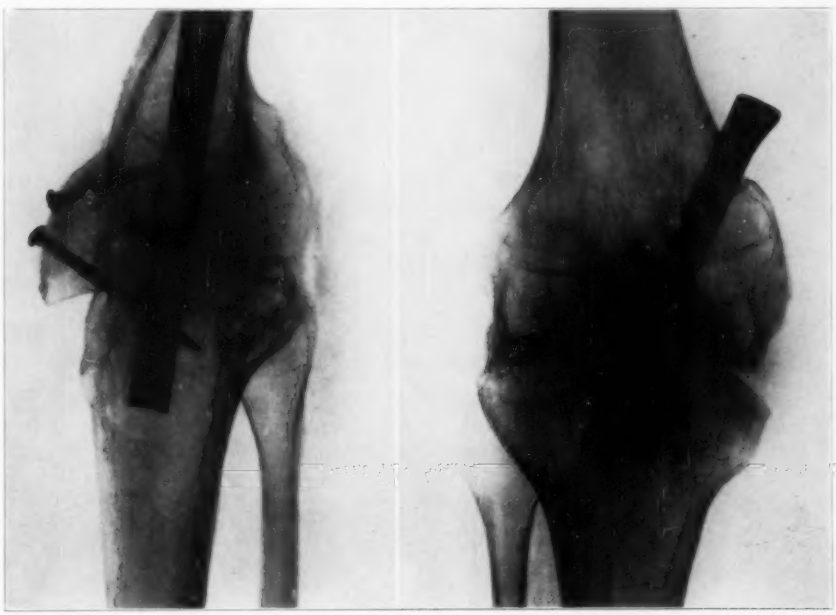

FIG. 2-B
January 6, 1947

Figs. 3-A, 3-B, and 3-C: Roentgenograms of B.R., a boy, fifteen years old, who had severe arthrogryposis with flexion-contracture of the knees. The left knee was resected and fused according to the Henderson technique with parallel Knowles pins. Union was solid in nine weeks.

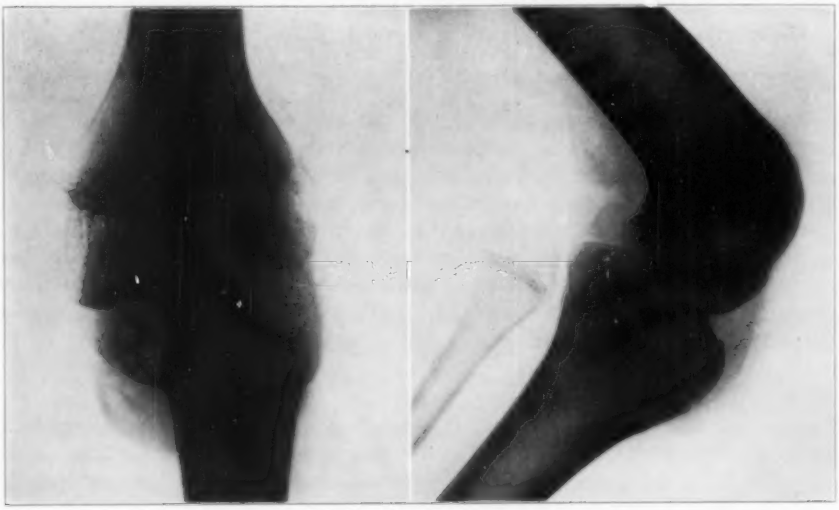

FIG. 3-A
October 25, 1955

FIG. 3-B
October 25, 1955

or prevent shortening when bone resorption does occur, is a deterrent to union.

In one of the patients with Charcot's joint, P.R., the crossed bone grafts and Knowles pins appeared to hold the knee apart (Figs. 1-A through 1-D). This occurred in a number of other conditions in which crossed pins, both of the Steinmann and the Knowles type, were used. In the one patient, L.J., who had tuberculosis, in whom a Smith-Petersen

nail was used, the same distracting force was present at surgery, but muscle pull produced collapse of the joint space, backing out of the nail, and a good result (Figs. 2-A and 2-B).

Interestingly enough, Henderson reported the use of parallel longitudinal Steinmann pins through the medial and lateral condyles of the femur and tibia. They were removed in approximately three weeks. Weight-bearing was allowed in five to six weeks, and union was said to occur in twelve to twenty weeks. This procedure was performed by one of the authors on a boy fifteen years of age who had severe arthrogryposis with congenital flexion-contracture of both knees. One knee was resected and fused by parallel Knowles pins and union was solid in nine weeks (Figs. 3-A, 3-B, and 3-C).

The three-flanged nail as used by Bosworth was intended to be almost parallel to the long axis of the limb. The more it approaches a transverse position, the greater the chance of distraction.

In one patient with tuberculosis, amputation was necessary because of sepsis. A probable contributing factor was that the Steinmann pins, passing through the infected area and out through the skin, made possible a superimposed pyogenic infection.

In all but six of the cases, some form of spica cast was employed postoperatively for an average of 12.1 weeks; these were followed by various forms of toe-to-groin casts and braces. The average time from operation to union for the series was 22.7 weeks, and ambulation began in an average time of 14.7 weeks. There were eight patients with non-union, one had an amputation, and two were not adequately followed. Thus, fifty out of sixty-one patients eventually obtained fusion.

ARTHRODESIS WITH COMPRESSION

Since August 1948, compression arthrodesis of the knee has been performed on thirty-seven patients by members of the Campbell Clinic staff. Thirty of these patients were followed long enough to permit critical evaluation and analysis.

One patient, R.H., who had displacement after surgery, required a second operative fusion and repositioning of the compression clamps. One patient, B.T., with severe Char-

FIG. 3-C
January 9, 1956

TABLE III

CONDITIONS NECESSITATING FUSION
Compression Arthrodesis

Condition	No. of Operations
Tuberculosis	5
Arthritis (pyogenic, degenerative, and rheumatoid)	10
Charcot's joint	2
Fracture	12
Tumor	1
Total	30

cot's joint, required thirteen months of immobilization before union occurred. The patient, I.R., who required the second longest time, eleven months, for final solid fusion, had, prior to the arthrodesis, an infected comminuted fracture of the tibial plateau (Figs. 4-A, 4-B, and 4-C).

Even though in many instances only a few months are necessary for evaluation of the fusion, no patient who was followed less than nine months was included. The average period of follow-up was 6.75 years. The most interesting single fact about this series is

Figs. 4-A, 4-B, and 4-C: Roentgenograms made of a fifty-two-year-old woman, I.R., who weighed over 200 pounds and who had an old comminuted fracture of the tibial plateau which had been infected at the time of an attempted open reduction. On July 21, 1949, a Key type of compression arthrodesis with turnbuckles was performed. The clamps were maintained for eight weeks, followed by toe-to-groin plaster for four weeks, followed by a toe-to-groin brace for seven months. The knee was clinically fused at eighteen weeks, but was not considered roentgenographically solid for eleven months. When last examined two and one-half years after surgery, it remained solid—finally a good result.

FIG. 4-A
July 13, 1949

that eventually union was obtained in all thirty patients, including the two with Charcot's joint and five with tuberculosis of the knee.

Analysis of Cases

These cases are reviewed according to the type and technique of compression operation, etiology, complications, and final observation.

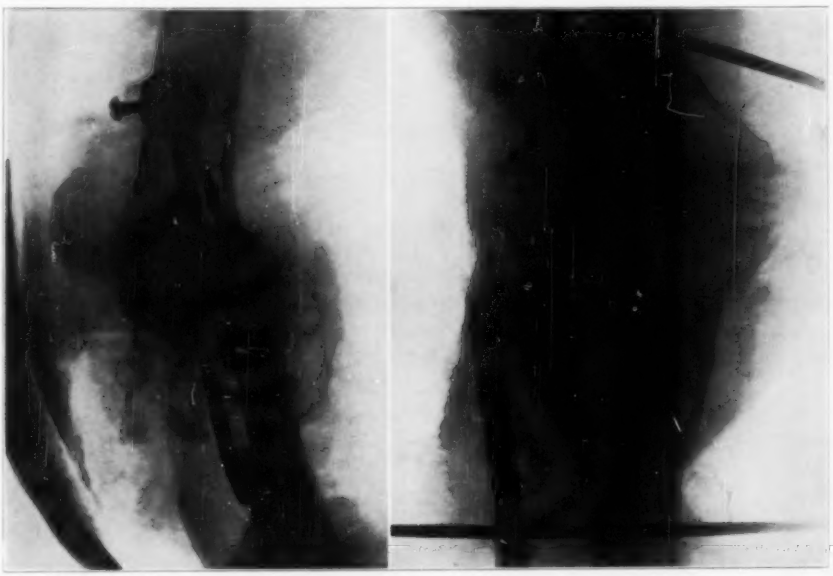

FIG. 4-B
August 9, 1949

FIG. 4-C
December 4, 1951

TABLE IV

TIME REQUIRED FOR FUSION

Compression Arthrodesis

Condition	No. of Operations	Average No. of Weeks		
		In Compression	In Plaster of Paris	Total
Tuberculosis	5	6.7	6.6	13.3
Arthritis (pyogenic, degenerative and rheumatoid)	10	7.6	6.9	14.5
Charcot's joint	2	7.5	7.0	14.5
Fracture	12	8.0	8.0	16.0
Tumor	1	7.0	6.0	13.0
Total	30	7.7	7.8	15.5

There were fourteen males and sixteen females. Sex showed no significant influence on the speed of union. The patients ranged in age from fifteen to seventy-seven years, the average age being 48.4 years. The mean age for the group was forty-nine years. The young and the old tended to achieve fusion more rapidly than the middle-aged. This tendency parallels the time required for healing of fractures.

Type and technique of compression: In five operations, the Key method of compression was used (four with turnbuckles, and one with rubber bands; all patients were immobilized in plaster). After its perfection, we adopted the Charnley clamp as the apparatus of choice, and it was used in twenty-five operations. We followed the dictates of Charnley as to placement of the pins and clamps. The femoral and tibial surfaces were prepared

Figs. 5-A, 5-B, and 5-C: Roentgenograms of a forty-two-year-old man, C.G., with tuberculosis of the knee of one year's duration. The knee was fused according to the Key turnbuckle technique on August 3, 1948. The pins were removed on October 5, 1948, and the knee was clinically solid; however, toe-to-groin walking plaster was continued for an additional eight weeks. One year later the result remained excellent, the knee solid.

FIG. 5-A
July 31, 1948

by cutting the cancellous surfaces with an amputation saw. The angle of flexion was predetermined, depending upon the etiology, the amount of shortening, and the occupation of the patient. In this series, twenty-one of the thirty knees were fixed in a position of between 160 and 170 degrees.

The mechanical alignment or anatomical fit of the bone surfaces at operation showed a definite influence upon the time required for healing. Patients with an excellent or anatomical alignment required an average of eleven weeks to show union roentgenographically, while those with a fair to good fit required an average of 19.9 weeks, nearly twice as long.

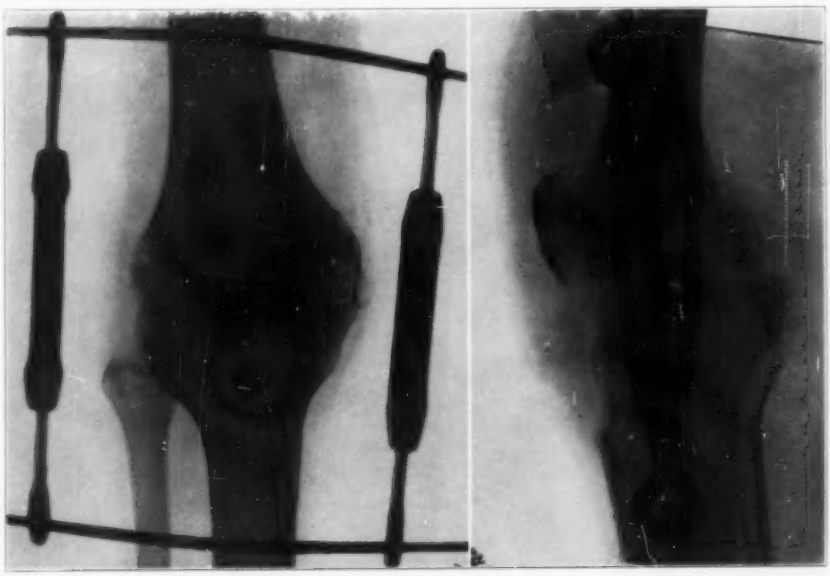

FIG. 5-B
October 5, 1948

FIG. 5-C
May 24, 1951

The amount of tension at the point of contact of the bone surfaces was not measured, but an evaluation was attempted which was based on the amount of bend or force on the pins. Two patients on whom there was a tension of only one plus (that is, slight bowing) required an average of 11.5 weeks for union. One patient on whom there was a tension of three plus—considered too much pressure because atrophy occurred—required fourteen weeks. The remaining patients, with a tension of two plus, required an average of 10.1 weeks for union. Charnley [4] recently reported that "in the special instance of cancellous

Figs. 6-A through 6-D: Roentgenograms of J.R., a thirty-two-year-old man who had tuberculosis of the knee of sixteen years' duration. A Charnley type of compression arthrodesis was done January 8, 1953. The knee was clinically fused in eight weeks when the clamps were removed but a toe-to-groin walking plaster was continued for an additional six weeks. When last examined four years later, the knee remained solid and the patient happy.

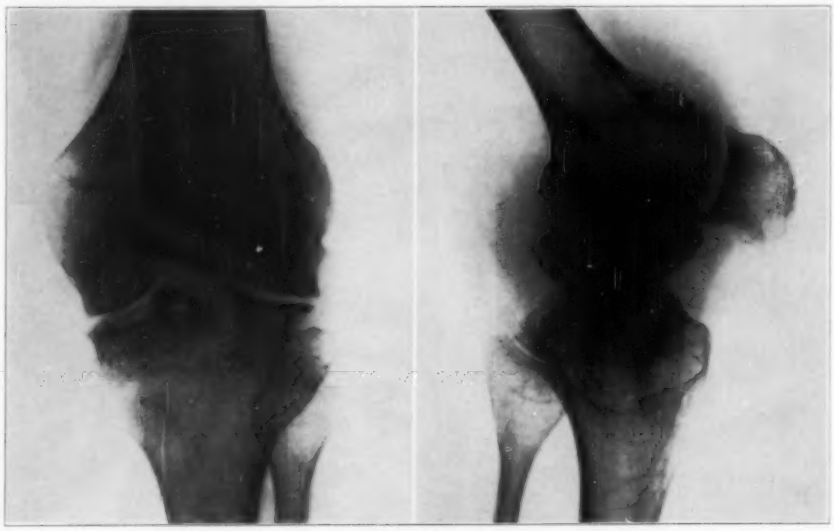

FIG. 6-A
January 2, 1953

FIG. 6-B
February 5, 1953

bone, mechanical compression actually stimulates osteogenesis," and his discussion implies that a pressure of about eighty pounds is ideal. "Knee-joints exposed to forces exceeding 80 lb. were absolutely solid four weeks after operation, but with forces of less than 60 lb. there was slight movement at four weeks (no 'first intention' osseous union)."

Often when the clamps were removed, the fusion was clinically solid and roentgenograms suggested adequate consolidation, but the surgeon was reluctant to trust so short a period of time to obtain union. Therefore, most of the patients were immobilized in toe-to-groin plaster for an additional period of time. Toe-to-groin braces, usually of the leather lacer type, were used in nine instances. Three of the patients with old fractures wore braces for an average of twenty-one weeks; three with tuberculosis wore them for an average of ten weeks.

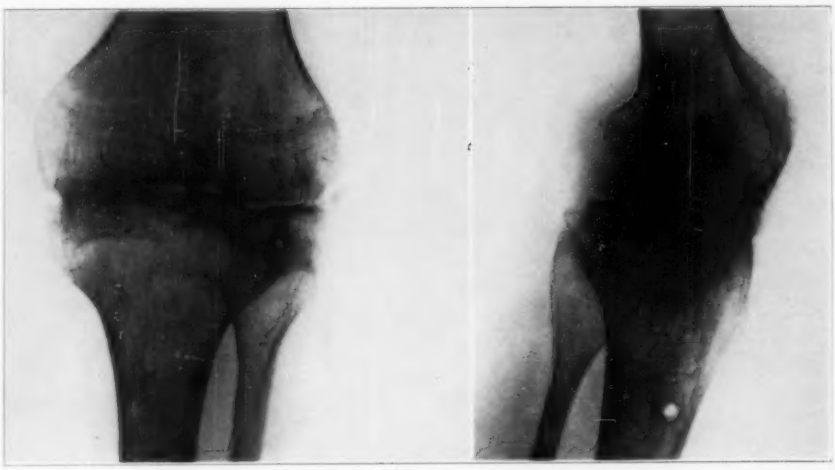

FIG. 6-C
March 13, 1953

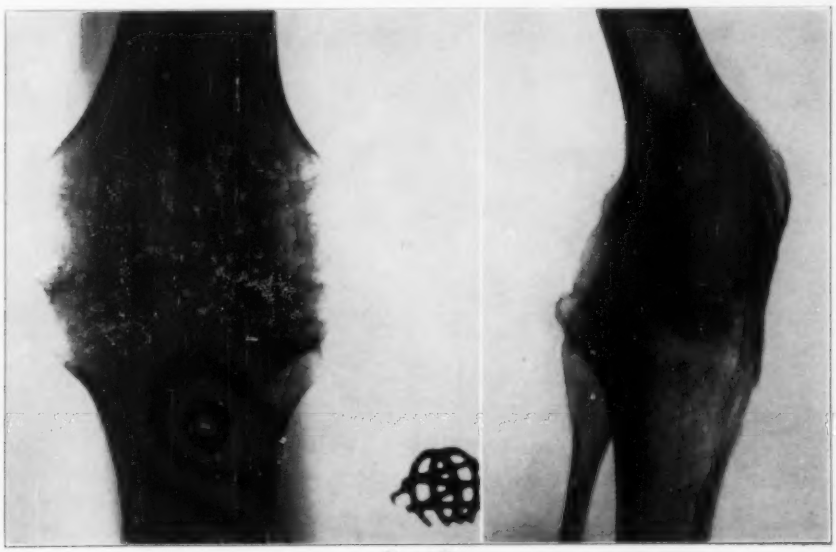

FIG. 6-D
December 20, 1956

Etiology: There were five patients with proved tuberculosis of the knee treated by compression arthrodesis; they all acquired solid bone union. The first operation of compression arthrodesis done at the Campbell Clinic was performed by one of the authors on a tuberculous knee in August 1948 (Figs. 5-A, 5-B, and 5-C). This patient, C.G., required only eight weeks in compression, by the Key turnbuckle method, before his knee was clinically solid. However, since this was the first patient treated by this method, we were reluctant to discontinue all support so early and his leg was placed in a toe-to-groin walking plaster for another eight weeks.

Figs. 7-A, 7-B, and 7-C: Roentgenograms of W.L., a thirty-five-year-old man who had degenerative arthritis and gout for fifteen years. A Charnley-clamp fusion was performed on February 23, 1956. The knee was clinically solid in six weeks when the pins were removed, but the knee was held in a toe-to-groin walking plaster for an additional ten weeks. The patient has continued at full weight-bearing since without support or pain.

FIG. 7-A
January 11, 1956

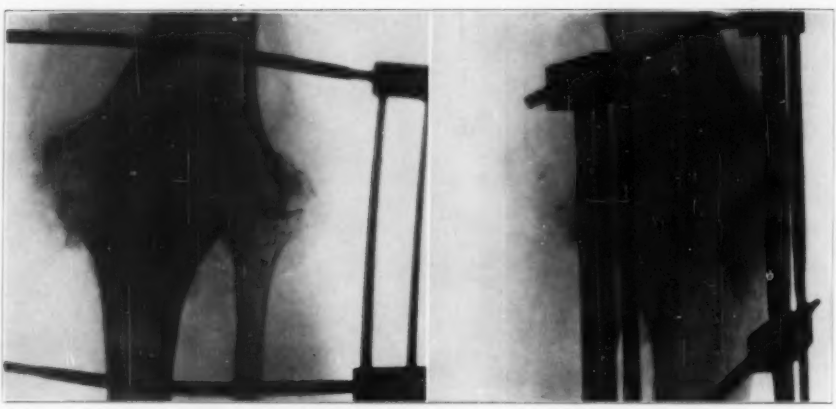

FIG. 7-B
April 5, 1956

Another patient (J.R., a man thirty-two years of age who was operated upon January 8, 1953), had had tuberculosis of the knee for sixteen years. A Charnley compression clamp was used (Figs. 6-A through 6-D). The knee was solid in eight weeks, but again a toe-to-groin walking plaster was used for an additional six weeks. Age and sex showed no influence upon the rate of union; however, five cases do not represent a sufficient series to be of any statistical significance. The important fact is that all these patients obtained bone union.

The various types of arthritis—pyogenic, degenerative, and rheumatoid—were grouped together, giving a series of ten cases. All patients in this group obtained solid bone fusion after an average period of immobilization of 14.5 weeks. There was no significant influence of sex or age upon the rate of fusion. However, in many of these patients, union was rapid. A thirty-five-year-old man, W.L., who had suffered with degenerative arthritis and gout for fifteen years, had a fusion with Charnley compression clamps (Figs. 7-A, 7-B, and 7-C). His knee was clinically solid at six weeks but he was kept in a toe-to-groin walking plaster for an additional ten weeks.

The two patients with Charcot's disease are probably the most interesting of the entire series because, although Charcot's joint is notoriously difficult to fuse, they both had final bone arthrodesis (Figs. 8-A through 9-C). After removal of the plaster of Paris, one of these patients (D.R.) wore a brace for two months, the other (B.T.) for four months. Wearing of the brace may not be necessary, but it is a safeguard in these difficult cases.

Old fractures with their inevitable vascular impairment and sclerosis were slow to unite, and thus required longer immobilization than any of the other groups. One patient, a forty-eight-year-old man, G.Z., had an old fracture of the medial femoral condyle which united in malposition (Figs. 10-A, 10-B, and 10-C). A compression arthrodesis by the Key method required only eleven weeks of immobilization, but the operation was performed fairly early after injury and through an area of good cancellous bone.

Another patient (I.R.), a fifty-two-year-old woman, with an old comminuted fracture of the tibial plateau had had infection at the site of the previously attempted open

FIG. 7-C
August 15, 1956

reduction. She required twelve weeks of plaster immobilization and protective bracing for an additional seven months before roentgenograms showed definite union (Figs. 4-A, 4-B, and 4-C).

One patient, a woman seventy-seven years of age, had a recurrence of a fibrosarcoma of low-grade malignancy in the proximal portion of the tibia. The tumor was resected and a compression arthrodesis performed. Her knee was clinically solid in seven weeks, but was immobilized in plaster for an additional six weeks. She then wore a brace for sixteen weeks, primarily because of her weakness and age.

Figs. 8-A, 8-B, and 8-C: Roentgenograms of D.R., a woman fifty-nine years of age who had Charcot's joint and was followed for three years as the knee gradually became grossly unstable. On June 24, 1953, a Charnley-type fusion was done. The clamps were removed in six weeks, followed by the use of a toe-to-groin plaster for six weeks. The knee was clinically solid after removal of the plaster but a toe-to-groin brace was worn for an additional eight weeks. Three and one-half years later the knee remained solid and painless.

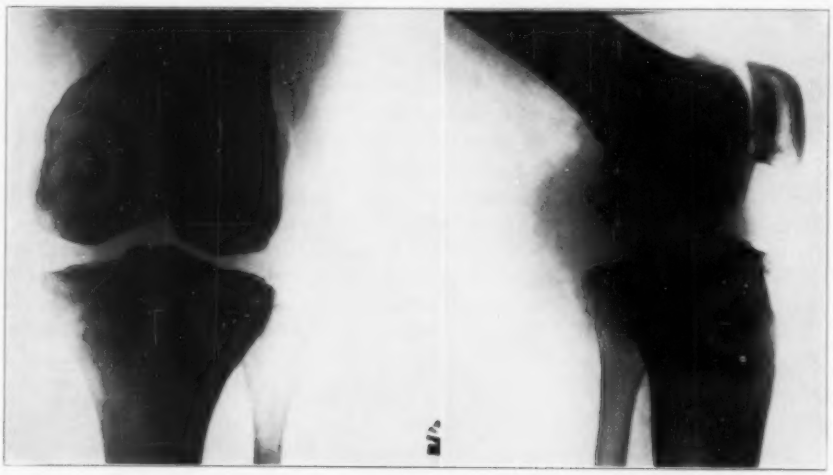

FIG. 8-A
June 8, 1953

FIG. 8-B
June 30, 1953

Complications: In the thirty-one operations there were four patients with pin-track infections. Three of the infections were mild and transitory; the fourth drained for six months, then healed without surgery.

One patient suffered vascular impairment; he was a forty-two-year-old man (M.J.) who had had a fracture involving the knee joint fifteen years previously. Degenerative arthritis developed; the patient also had paralytic foot-drop at the time of the original injury. After a Charnley fusion, the knee was clinically and roentgenographically solid at eight weeks, but an arterial insufficiency resulted in an anterior-tibial compartment slough. Surgery was required to remove the necrotic tissue; skin-grafting was then done. After nine months the leg healed, and the patient continued ambulatory in a drop-foot brace.

Observations

The most interesting feature in this series is that all thirty patients had final bone fusion.

In one patient (R.H.) two operative procedures were required. This patient was a man thirty-five years of age who, in 1941, had a severe fracture involving the right knee, resulting in fibrous ankylosis. In May 1951 he had a compound fracture-dislocation of the ankylosed knee. After thorough débridement, a primary Charnley fusion was performed. The wound remained clean and healed by primary intention, but after seven months motion in the joint was elicited clinically. A second operation with refitting of the joint surfaces and replacement of the pins and Charnley clamps resulted in solid union in ten weeks.

The achievement of arthrodesis in the two patients with Charcot's joint was surprising and gratifying. The five knees with proved tuberculosis all united, and in an unexpectedly short time.

Postoperative immobilization in the majority of patients was in plaster of Paris; however, a Thomas or Hodgen splint was used successfully in several instances. No patient

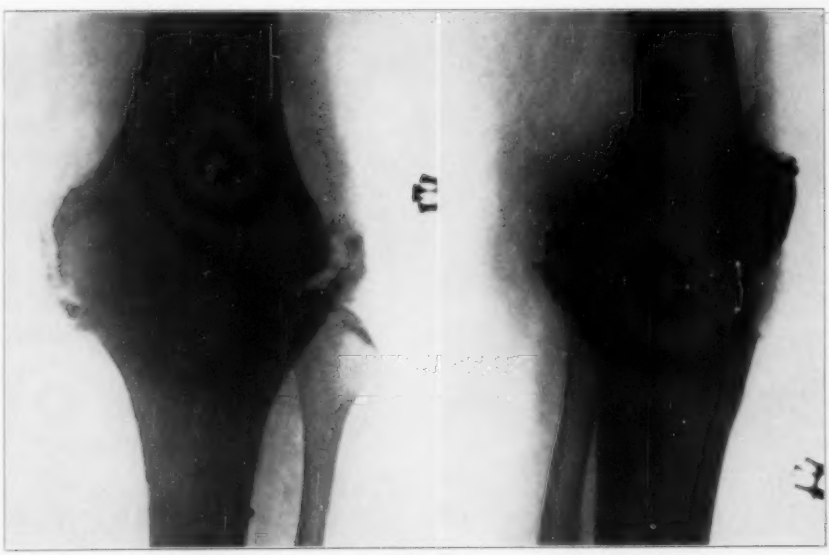

FIG. 8-C
September 12, 1953

had any residual pain in the knee after union. The average amount of shortening among the thirty patients was 1.27 inches.

The position of the knee after fusion ranged from 135 degrees to 180 degrees. The majority (twenty-one) were between 160 degrees and 170 degrees. As previously noted, the final position was dependent on many factors, the most important being the patient's occupation.

Figs. 9-A, 9-B, and 9-C: Roentgenograms of B.T., a forty-nine-year-old woman with a positive Wassermann test who had severe Charcot's disease of the right knee. On June 16, 1955, a Charnley-type fusion of the knee was done. The pins were removed at nine weeks, and a toe-to-groin plaster was used for an additional nine months. She then wore a brace for four months; however, the knee was clinically solid when the plaster was removed. She was last seen eighteen months after surgery and the knee remained solid and the patient well satisfied.

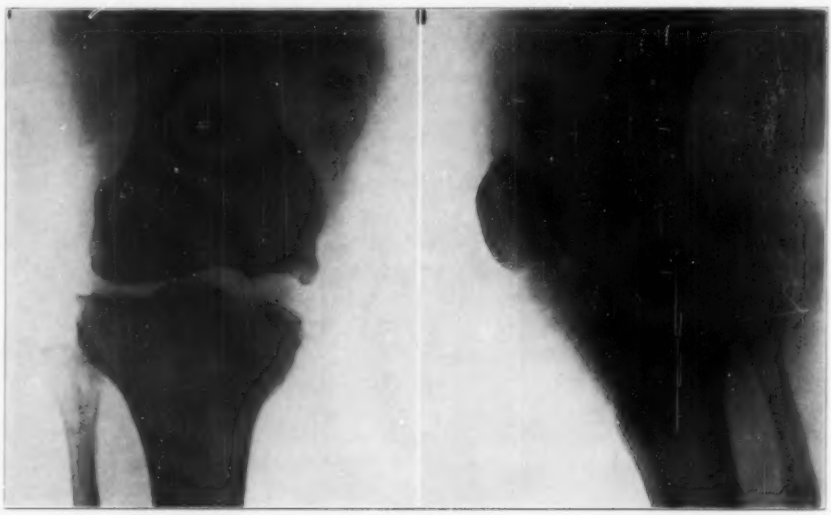

FIG. 9-A

September 9, 1954 June 1, 1955

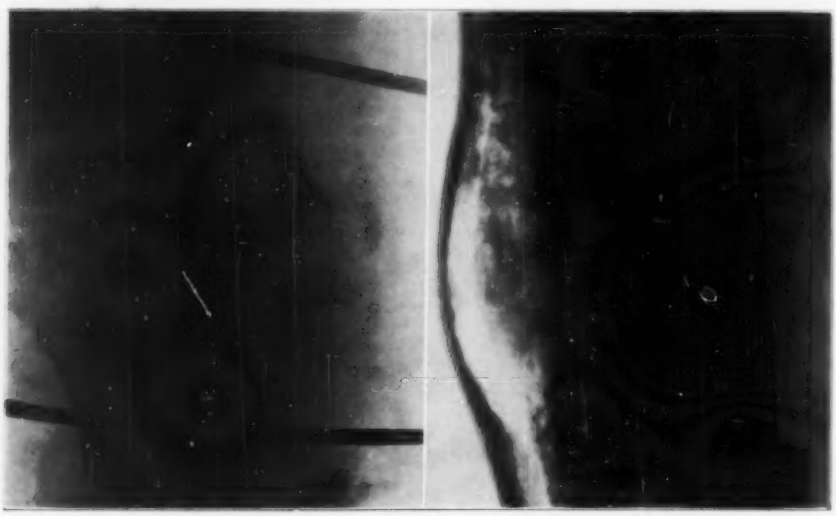

FIG. 9-B

July 19, 1955

DISCUSSION

The principles of resection and fusion of diseased joints have been appreciated and practiced in various forms for nearly two centuries. By these means, the surgeon has continually striven to control severe chronic infections such as tuberculosis, degeneration of all types, and gross instability. But it is only within recent years, after thorough appreciation of the physiology of bone healing, with the introduction of modern antibiotics, and with the improvement of surgical techniques, that the present concept of arthrodesis has been established.

There is little doubt that good bone contact of the surfaces to be fused is the prime requisite for obtaining union. Key [9,10], Eggers [5,6], Charnley [2,3], and others believed that positive pressure will best maintain this contact, because it assures a good fit, good stability, and rigid immobilization. Charnley [4] is now convinced that this positive pressure also stimulates osteogenesis.

In a comparative review of the arthrodeses of the knee performed at the Campbell Clinic during the last twenty-five years, it was found that compression arthrodesis consistently gave the best results and required the shortest time for union. Bones with difficult conditions such as tuberculosis and Charcot's disease were often slow to unite, but solid bone fusion was eventually obtained in all the patients in whom compression arthrodesis was used. No other method of fusion offers such satisfactory results.

In many instances, crossed-pin fixation and cortical-graft fixation are deterrent to union because of their tendency to hold the bone surfaces apart. On the other hand, parallel or intramedullary pins properly placed will allow compression by muscle action or weight-bearing and any gap between the surfaces can be closed.

The method of securing the pressure in compression arthrodesis of the knee, whether by turnbuckle (Key) or by compression clamps (Charnley), or by other means, is of little importance as long as adequate pressure can be maintained. However, the fitting of good cancellous surfaces in correct position is of extreme importance. It would be of considerable benefit if the amount of compressive force exerted at the point of bone contact could be measured and the optimal pressure established.

After the proper force has been exerted on the clamps and pins, then immobilization in either plaster of Paris or a Thomas splint is satisfactory. After removal of the compres-

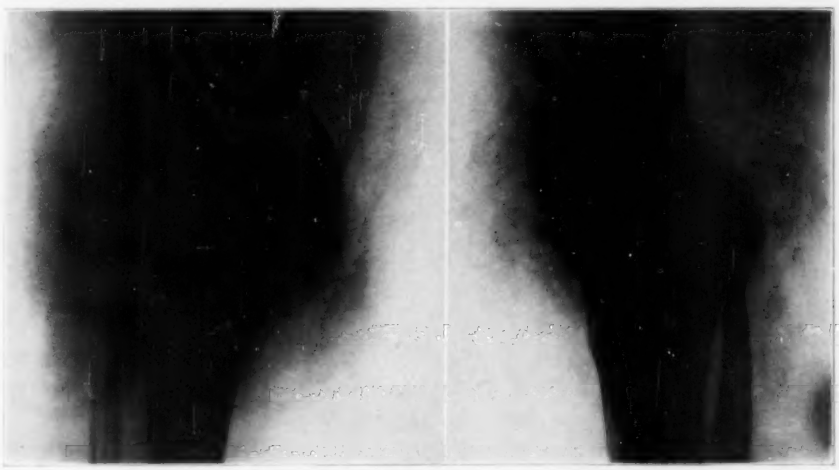

FIG. 9-C
September 12, 1956

Figs. 10-A, 10-B, and 10-C: Roentgenograms of G.Z., a man forty-eight years of age who was seen seven months after he had a fracture-dislocation of the medial femoral condyle of the right femur. At surgery it was found that there was severe arthrofibrosis with destruction of the articular cartilage. A Key-type arthrodesis was performed on February 20, 1949. The pins were removed at six weeks. A toe-to-groin walking plaster was used for five weeks, following which the knee was clinically solid and the patient was allowed full weight-bearing without support. He continued work as a railroad-grade flagman.

FIG. 10-A
April 14, 1949

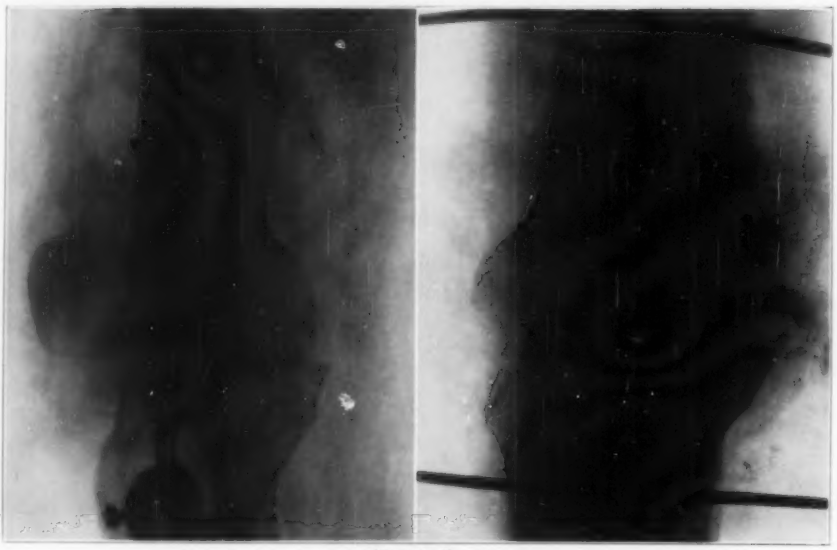

FIG. 10-B
September 1, 1949

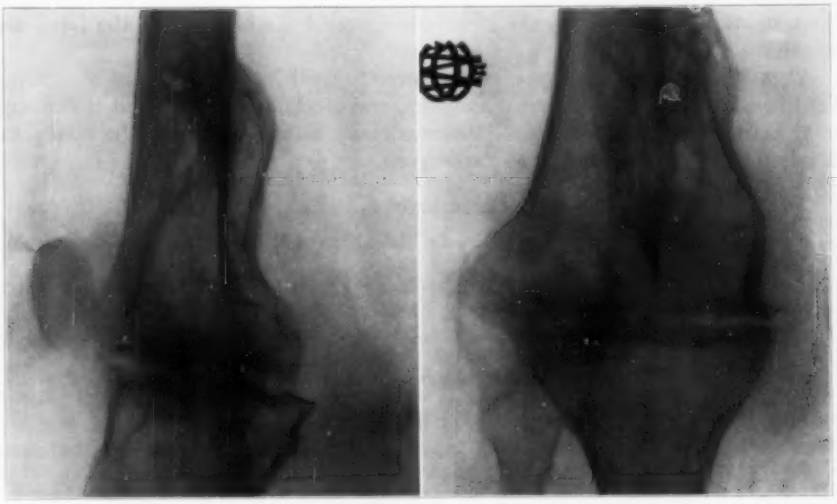

FIG. 10-C
February 2, 1950

sion apparatus, which will, in the majority of patients, be from six to eight weeks, a toe-to-groin walking cast for an additional six weeks is advisable. In children, the additional protection of a brace may be necessary for several months.

Cortical-bone grafting or the addition of bone chips was not necessary in compression arthrodesis, but in the majority of our operations the patella was used as an anterior bridge. It is denuded of all cartilage, then placed in a prepared bed in front of the femur and tibia, thus bridging the joint space. Postoperatively, the patients were usually quite comfortable and were allowed to leave the hospital in from seven to ten days.

It is well known that compression arthrodesis is applicable to some other joints as well as to the knee. At the Campbell Clinic, for example, more than thirty ankles and one hip joint have been fused by this method of compression.

SUMMARY AND CONCLUSIONS

Of ninety-three arthrodeses of the knee joint performed at the Campbell Clinic, sixty-three followed the so-called conventional methods and thirty the compression method.

The average time required for clinical and roentgenographic union in the series with the compression technique was less than half as long as that in the series with conventional arthrodesis. Ambulation, too, was possible much earlier in the compression series.

In patients with difficult conditions such as tuberculosis, union was obtained by the compression method. With the conventional method, union occurred in only 75 per cent and required nearly twice as long.

Only four instances of Charcot's disease occurred in the series. In the two patients with compression fixation union was slow, while the ones treated by the conventional methods had non-union.

In patients with severe fractures involving the knee joint a longer time for union was required than the over-all average. This delay was probably due to the amount of sclerosis which developed as a result of the trauma and impairment of the blood supply.

Chapchal's method of intramedullary fixation across the knee joint has not been tried at the Campbell Clinic; however, the principles of his method are in accord with the contemporary concepts of the requirements for arthrodesis and fracture healing. In the one

patient treated by the Henderson technique (parallel Knowles pins), the joint united promptly.

When the compression apparatus is correctly used in arthrodesis of the knee, the patient is spared much morbidity, discomfort, and disability. It is evident that compression arthrodesis of the knee joint possesses many advantages over the conventional method, both to the patient and to the surgeon.

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SCOLIOSIS

EDITORIAL

(continued from page 510)

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The Treatment of Certain Cervical-Spine Disorders by Anterior Removal of the Intervertebral Disc and Interbody Fusion *

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INTRODUCTION

The purpose of this paper is threefold: to describe a surgical procedure for removal of cervical intervertebral discs and for fusion of the cervical spine by the anterior approach [16], to outline some indications for this procedure, and to report the results in the first fourteen patients in whom this surgical procedure was employed.

Disc degeneration, with or without accompanying osteophyte formation, subluxation, instability of one cervical vertebra on another, or intervertebral-disc protrusion is the pathological change usually associated with neck, suprascapular, interscapular, occipital, arm, hand, and chest pain stemming from the cervical spine.

In the authors' experience intervertebral-disc degeneration with accompanying osteophyte formation (osteo-arthritis or spondylosis of the cervical spine) is the most common pathological change associated with neck, shoulder, arm, and hand pain [5, 6, 7, 9, 13]. Of the fourteen patients reported here, ten had these changes associated with cervical-nerve-root irritation or compression. Three patients had disc degeneration alone [8]. This degeneration, not yet accompanied by visible osteophyte formation or significant disc narrowing, was demonstrated by discography. One patient had cervical subluxation and, in addition to pain in the neck, shoulder, and left arm, also had long-tract signs due to spinal-cord involvement secondary to the spine instability.

The position and size of osteophytes are important in the cervical spine. Those arising from the posterolateral vertebral-body joints (joints of Luschka) may impinge on cervical-nerve roots, on the vertebral artery, or on both [7, 10, 12]. Those protruding posteriorly from the margin of a vertebral body may impinge on the spinal cord and the anterior spinal artery. However, even when osteophytes obvious by roentgenogram protrude into the intervertebral foramina, symptoms may not be present. Therefore, although the position and the size of these osteo-arthritic spurs are important, even more important in our opinion is the mobility of the neck at the level where the osteophytes occur.

Non-operative therapy is often effective in relieving head, neck, shoulder, and arm pain in the majority of patients [9, 15]. This may require permanent reduction in daily activity and frequent use of traction, or of a stabilizing collar device. If conservative treatment fails to relieve the pain, or if the pain becomes excessively burdensome to the patient, then surgery is indicated.

The results of laminectomy are usually satisfying when used for relief of pressure due to posterior osteophytes impinging on the spinal cord [2, 18, 23] or due to acute cervical-disc protrusion [3, 4, 14, 20, 21, 22].

Laminectomy is not so satisfying when posterior osteophytes compress nerve roots in an intervertebral foramen. Enlargement posteriorly of the intervertebral foramen, by removing the articular facet, as well as laminectomy may be necessary to relieve nerve-root pressure in the foramen. Unilateral excision of a posterior articulation may not cause spine instability, but when pain is bilateral adequate decompression of both intervertebral foramina at the same level may lead to instability.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1957.

If the source of trouble is a degenerated disc with or without osteophytes one would like to remove that disc, but in the neck the removal of a degenerated but non-prolapsed disc is not feasible or desirable by means of posterior laminectomy.

If enlargement posteriorly of the intervertebral foramen has been extensive and is followed by symptoms of cervical-spine instability or if pain has not been relieved by enlargement of the foramen and laminectomy, then fusion of the cervical spine is desirable. After an extensive laminectomy this is often difficult by the posterior approach since the usual anchor points for the bone grafts have been removed at the time of laminectomy.

If the symptoms are due to osteo-arthritic spurs impinging on nerve roots in the intervertebral foramina, particularly if the symptoms are bilateral or if due to disc degeneration or subluxation with or without missing posterior articulations, then in our opinion, disc removal and fusion of the cervical spine by the anterior approach is indicated. We therefore present our results with an operation that appears to achieve this goal. In our hands this operation (1) has less morbidity than laminectomy and foramen decompression or posterior fusion of the cervical spine; (2) allows one to remove a degenerated disc without disturbing the spinal canal; and (3) permits interbody fusion of the cervical spine at the specific intervertebral level from which symptoms arise.

Employing eight dogs, the authors found that the anterior surgical exposure of the cervical vertebral bodies and disc spaces is a reasonably safe procedure and that it is feasible. The intervertebral-disc material could be extensively removed from between the vertebral bodies through the anterior approach without damage to the spinal cord. Bone plugs from the ilium could be placed between the vertebral bodies in the interspace from which the disc material had been removed. This procedure was used by the authors on a patient for the first time in February 1954. A surgical exposure similar to that worked out on dogs by the authors was used by Lahey [11]. However, he used it as a method of exposing esophageal diverticula and did not suggest this approach for exposing the bodies of the cervical vertebrae.

LOCALIZATION OF THE OPERATIVE LEVEL

The level at which the operation is to be carried out should be precisely localized preoperatively; the first step is the physical examination. There may be sensory deficits in a single nerve-root distribution. Specific muscle weakness in the arm and hand or reflex changes at the tendons of the biceps and triceps brachii or at the radial styloid process may point to the level of nerve-root compression. Occasionally involuntary twitching will be observed in some group of muscles referable to a particular nerve root.

Irritation or compression of the nerve roots emerging between the fourth and fifth and fifth and sixth cervical vertebrae commonly produces tenderness of the radial nerve and pain radiating to the thumb and index finger. A lesion between the sixth and seventh cervical vertebrae may refer pain to the middle finger, while lesions between the seventh cervical and first thoracic (and occasionally between the sixth and seventh cervical vertebrae) refer pain to the little finger. Prolonged hyperextension of the neck (one minute by the clock) may aggravate the pain in the neck, shoulder, and arm and even cause a clear radiation to one of the digits. With the patient sitting, downward compression applied to the head with the neck tilted to either side may cause a clear pain-radiation pattern which will facilitate localization of the lesion in the neck [4].

The second step is trying to localize the involved cervical-spine level by simple roentgenography. Sometimes anteroposterior, lateral and right and left oblique roentgenograms of the cervical spine will enable one to localize definitely one isolated level (Fig. 1-B). For instance, between the fifth and sixth cervical vertebrae isolated disc degeneration and osteophyte formation may be obvious. Lateral roentgenograms made with the patient sitting or standing while he first flexes and then extends the neck may show a level of excess or limited motion between two vertebral bodies or an interruption at one level of the normally smooth curve of vertebral alignment.

FIG. 1-A

FIG. 1-B

Figs. 1-A through 1-D: Roentgenograms showing the sequence of events during cervical-disc degeneration.

Fig. 1-A: Lateral roentgenogram of the cervical spine made in 1950, three years after the onset of symptoms, shows what appears to be a practically normal intervertebral disc between the fifth and sixth cervical vertebrae. At that time, the patient complained of pain in the neck, some right occipital headache, and tenderness and spontaneous pain over the medial superior corner of the scapula with some general aching in the right shoulder.

Fig. 1-B: Roentgenogram made in 1955 shows narrowing of the fifth and sixth cervical intervertebral-disc space with anterior and posterior bone-spur formations.

FIG. 1-C

FIG. 1-D

Fig. 1-C: A myelogram, made at the time of the roentgenogram seen in Fig. 1-B, shows the encroachment of the posterior spurs and overlying soft tissues on the dural sac which has been outlined with pantopaque.

Fig. 1-D: The bridge of bone is shown which has formed between the fifth and sixth cervical vertebral bodies following anterior removal of the intervertebral disc and interbody fusion. No motion could be seen in the cervical spine in lateral roentgenograms made while the patient flexed or extended his neck and a bone bridge between the two vertebral bodies was obvious. This is considered a solid bone fusion.

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Case 3. Lateral view showing the extravasation of the contrast medium posteriorly under the posterior longitudinal ligament at the sixth and seventh cervical vertebral interspace.

Fig. 2-B: Case 3. Anteroposterior view of the same cervical spine showing irregular spread of the contrast medium throughout the disc space bilaterally, and through the joints of Luschka into the region of the intervertebral foramina.

Fig. 2-C: Case 14. A slightly oblique view made to show the spread of the contrast medium through the joint of Luschka into the intervertebral-foramen area. One may note that on the side of the neck, opposite to that of the arrow, a previous foraminotomy had caused removal of an articular-facet joint at the fifth and sixth cervical vertebral interspace. Symptoms had recurred subsequently on the side opposite the foraminotomy site. Foraminotomy on the side of recent symptoms would have probably necessitated partial or complete removal of the one remaining articular-facet joint at this level. Therefore, disc removal and fusion was performed to avoid instability at this level.

If such an isolated level by roentgenographic and physical findings corresponds (within anatomical limits of variability), one can be fairly certain that the level for surgery has been located.

However, plain roentgenograms and physical examination may show no well developed disc degeneration (Fig. 1-A) or the physical findings may suggest that, although one level appears abnormal by roentgenogram, physical signs and symptoms are arising from another level. Therefore, as a third step to localize precisely the involved level, special diagnostic methods may be necessary. Discograms (Figs. 2-A, 2-B, and 2-C) were made preoperatively in all of our group of fourteen patients. Myelography was done on only two patients and then only because of questionable long-tract signs (Fig. 1-C). Contrast material was injected by means of a needle inserted anterolaterally approximating the route of the anterior surgical approach to the cervical intervertebral discs. In most cases

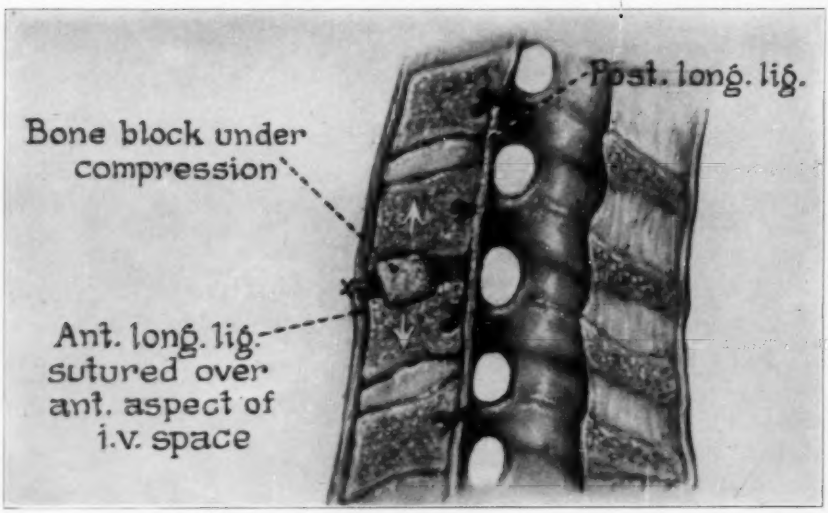

FIG. 3

Diagram showing the block of bone in place between two cervical vertebral bodies. One will note that the bone block is countersunk below the anterior longitudinal ligament so that the ligament may be resutured over it.

FIG. 4-A

FIG. 4-B

Roentgenograms made in flexion (Fig. 4-A) and in slight extension (Fig. 4-B) six months postoperatively of patient in Case 13. There is a bone bridge between the fifth and sixth and between the sixth and seventh cervical vertebral interspaces. There was no demonstrable motion. However, at the sixth and seventh cervical interspace the bone graft was not as well countersunk as that at the fifth and sixth. Although there was complete relief of symptoms at that time, there was no increase in the height of the intervertebral space secondary to operation at the sixth and seventh interspace and the interspace between the fifth and sixth cervical vertebrae showed only the preoperative height.

FIG. 5-A

FIG. 5-B

Lateral roentgenograms of the cervical spine made in flexion and extension in the patient in Case 7 fourteen months after surgery when all the symptoms had been relieved. It will be noted that there is a bone bridge between the fifth and sixth and sixth and seventh vertebral bodies, most apparent between the fifth and sixth vertebrae. Comparison of these two roentgenograms showed no evidence of motion at these two levels and the fusion was considered solid.

the injection of contrast medium at the involved level reduplicated or exaggerated the typical pain pattern. Discography was therefore useful in those patients in whom there were multiple disc narrowings and in whom it was not clear which of the multiple levels was the source of the major complaint. In some cases the discogram showed only a slightly abnormal pattern at a level where nerve-root signs suggested the probable location of trouble, whereas a discogram made at another possible pain-producing level demonstrated the site of election for surgery by an extremely abnormal roentgenographic pattern in addition to clear reduplication of the pain. This procedure was also useful in those patients with disc degeneration in whom both narrowing of the disc and spur formation were not remarkable by roentgenogram (Figs. 2-A, 2-B, and 2-C).

OPERATION

The patient is under general anaesthesia and should be intubated. Intubation *via* the mouth often requires a degree of neck extension which may be dangerous in the presence of extensive hypertrophic changes on the posterior edges of the vertebral bodies because of possible spinal-cord injury. Therefore, intranasal intubation is recommended in such situations. The patient is placed on the operating table in a supine position. A small pad is placed between the scapulae just caudad to the neck allowing slight head and neck extension. The chin is turned about 10 degrees to the right. Traction of twenty pounds may be applied to the head by means of a halter.* The skin over the left anterior portion of the neck and the right iliac crest is prepared for surgery and the areas draped. A transverse incision is made along a skin crease at about the level of the fifth cervical vertebral body, to the left of the mid-line and about three finger-breadths above the clavicle. If the incision is made high on the neck one must be careful to avoid perforating the pharynx above the glottis. If the spine is not too heavily encased in soft tissue the carotid tubercle on the sixth cervical vertebra can be palpated before the incision is made. If the operation is to be at the fourth, fifth, sixth, and seventh cervical vertebral levels, the incision should be just at or a little above this deep osseous identifying structure.

* This has become routine practice at the Johns Hopkins Hospital.

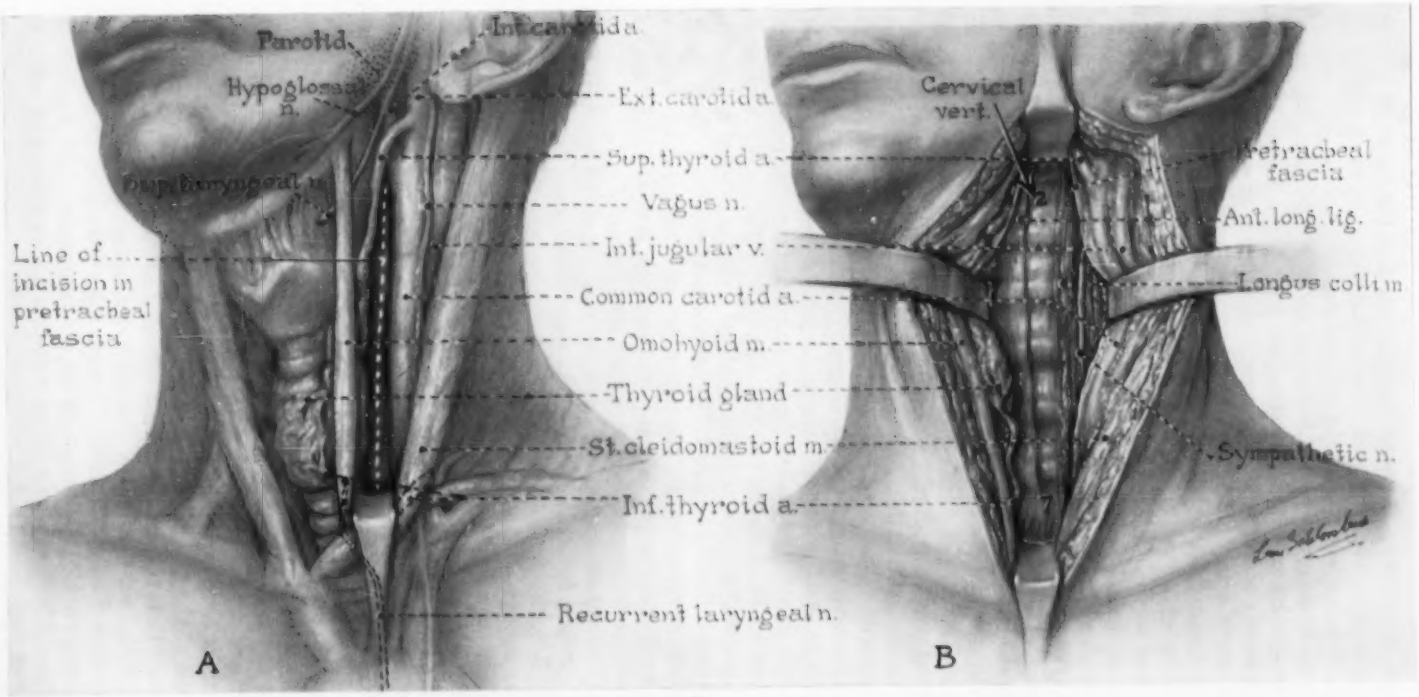

FIG. 6

Drawing showing the operative approach to the cervical spine. The flexibility of the anterolateral approach to the cervical spine depends on several factors. First, if several vertebral bodies are to be exposed between the second cervical and first thoracic levels, a slightly oblique vertical incision following the anterior border of the sternocleidomastoid muscle may be used. If only one or two vertebral bodies are to be exposed, a short transverse incision at the appropriate level may be used. (Detailed descriptions of the transverse and vertical incisions may be found on page 635 of the June 1957 issue of *The Journal*.) Second, the omohyoid and sternocleidomastoid muscles may be retracted freely, thus exposing the pretracheal fascia that covers the entrance to the interval between the structures in the carotid sheath and those in the mid-line compartment of the neck. Third, by incising the pretracheal fascia parallel to the carotid artery, one passes through the areolar tissue directly to the thin prevertebral fascia. Fourth, one can pass freely between the mid-line structures of the neck and the carotid sheath since there is a long interval between the origin of the superior thyroid artery and the origin of the inferior thyroid artery where no important nerves or arteries pass. Finally, the prevertebral fascia on the floor of the interval between the mid-line and lateral structures of the neck forms a thin transparent cover over the anterior longitudinal ligament, the anterolateral portion of the vertebral bodies, the longus colli muscles, and the sympathetic nervous system. The fascia can be incised vertically over the vertebral bodies and retracted to either side so that the operative site is directly exposed for intervertebral-disc removal and interbody fusion.

The incision is made on the left since the possibility of traction on the recurrent laryngeal nerve appears less than if the right side is used. The incision should be about eight to ten centimeters in length. It is carried through the skin, subcutaneous tissue, and platysma muscle. A vertical incision along the medial border of the sternocleidomastoid permits one to retract that muscle laterally and to retract the sternohyoid, sternothyroid, and omohyoid muscles medially and inferiorly. The carotid sheath is then seen in the center of the wound and the carotid-artery pulse should be palpated. If neck extension makes this difficult the anaesthetist may flex the patient's head and neck slightly until a good pulse is definitely palpated. A second vertical incision is then made through the pretracheal fascia just medial to and parallel with the carotid artery. The areolar soft tissue beneath this incised fascia is then spread with the fingers between the structures in the center of the neck (the thyroid gland, trachea, and esophagus) and the carotid sheath laterally. With impunity a superior or inferior thyroid artery and vein may be ligated and divided to give better exposure although in our experience this was rarely necessary unless the first thoracic or second cervical vertebra was exposed. The danger of perforating the esophagus is avoided by confining the exposure to the area between the medial and lateral structures of the neck. The carotid sheath and the sternocleidomastoid muscle are retracted laterally with a thyroid retractor. The sternohyoid, sternothyroid, and omohyoid muscles, the esophagus, trachea, and thyroid gland are retracted medially with a medium-sized Richardson retractor. Thus are exposed the prevertebral muscles and the anterior longitudinal ligament behind the esophagus. The two retractors are relaxed at ten-minute intervals to avoid prolonged tracheal or carotid-sheath pressure (Fig. 6).

The surgeon should palpate the underlying bone structures at this point from one side to the other of the neck to locate the mid-line. Thus the possibility of mistaking the irregular transverse processes for osteo-arthritic vertebral bodies is avoided and perforation of the vertebral artery is thereby obviated. The transparent prevertebral fascia is then vertically incised over the vertebral bodies. The cervical sympathetic trunk lies under this fascia over the longus colli muscles just lateral to the vertebral bodies. The longus colli muscles lie over the transverse processes of the cervical vertebrae.

The anterior longitudinal ligament glistens over the mid-line of the vertebral bodies even through the prevertebral fascia. It clearly marks the mid-line when the prevertebral fascia is drawn aside. By cleaving to the mid-line and making sure that the tip of the lateral retractor does not press on the region of the ascending sympathetic-nerve fibrils, the surgeon avoids a postoperative Horner's syndrome.

When osteo-arthritic spurs are present at only one or two intervertebral levels they can be palpated through the anterior longitudinal ligament. At this point a metal object such as a spinal needle is placed in the suspected disc space and a lateral roentgenogram is made in the operating room to confirm the position of the involved intervertebral level. (If one desires, a discogram may be made at this time.)* A fairly reliable identifying structure is the carotid tubercle which may be palpated through the wound and is usually part of the sixth cervical vertebra. Occasionally, it is found on the seventh cervical vertebra but if there is doubt about this anatomical variant its presence may be noted in the lateral roentgenogram as a shadow overlying the cervical body, usually the sixth.

A flap of the anterior longitudinal ligament is then turned back over the indicated disc space. The middle of the flap directly over the disc is intimately attached to the pellicle and the annulus. Thus the middle of the flap must be raised by sharp dissection. This flap is then laid back from the front of the disc space but remains attached to the right side of the anterior longitudinal ligament. Through this aperture the intervertebral-disc material, including the nucleus pulposus and the cartilage plates which separate the intervertebral-disc material from the bone of the vertebral bodies above and below the

* Discograms made during surgery rather than before have become the more common practice. This avoids the pain associated with the procedure, but gives only objective evidence of disc degeneration.

disc, is removed with pituitary rongeurs and curettes. If the anterior osteophytes are large and overhang the disc space they may have to be pared back a little to expose the disc space and to permit insertion of a curette and pituitary rongeur, but an effort is made to preserve the anterior cortical edges of the vertebral bodies adjacent to this disc space. In this way there remains, after the removal of the soft tissues in the disc space, a superior and inferior cortical-bone edge posterior to which the bone graft may be countersunk. Thus these cortical edges of the adjacent vertebrae are preserved to hold the bone block in place when the neck is brought to a normal neutral position, between flexion and extension, after surgery. The bone should be exposed by removal of the cartilage plate and subchondral bone at the top and at the bottom of the intervertebral-disc space if osseous union is to be subsequently expected between the adjacent vertebral bodies. The space is then measured. The space usually accepts a block of bone ten to fifteen millimeters high, ten to fifteen millimeters wide, and ten to fifteen millimeters deep.

A short incision is then made over the crest of the ilium and a suitable piece of iliac bone is obtained with a sharp osteotome to fill the space between the two cervical vertebral bodies. The size of the bone plug removed from the ilium should be greater than the final size of the trimmed block. Two vertical cuts, two centimeters deep, are made about two centimeters apart along the top of the iliac crest. The rough bone plug then measures about two by two by two centimeters, a full thickness of the crest. The iliac wound is closed and the bone graft is shaped. As cut from the ilium it is horseshoe-shaped and consists of cancellous bone surrounded on three sides by cortical bone. The top, bottom, and one end of the bone graft, as it is to be used in the intervertebral space, are cancellous. The cancellous end is inserted into the disc space. The cancellous top and bottom surfaces of the graft lie against the previously exposed cancellous surfaces of the superior and inferior vertebral bodies while the cortical exterior of the graft assumes a vertical position in the intervertebral space.

The prepared intervertebral space is then widened as much as possible by extending the patient's neck. The vertebral-body edges may be further spread apart with bone hooks or wedging devices. The head-neck traction helps to widen the intervertebral space when the disc material has been removed. The bone graft, when inserted into the intervertebral aperture, is tapped into position with a tamper and is countersunk in relation to the anterior cortical edges of the intervertebral aperture (Figs. 4-A and 4-B). When it has been seated it should be very stable. After hemostasis is complete, the flap of anterior longitudinal ligament is repositioned over the intervertebral aperture by two or more sutures.

The soft tissues are allowed to fall together. Sutures are placed in the fascial sheath of the platysma, the subcutaneous tissue, and the skin. A dry sterile dressing may be placed over the wound. No immobilization of the neck is used at this time.

POSTOPERATIVE COURSE

The arm pain may not disappear at once although the preoperative neck and suboccipital pain are usually absent immediately following surgery. One or two days postoperatively the patient is permitted to be up and walk. At four days the skin sutures are removed. The patient is allowed to go home about five to seven days after operation. When one space has been fused it has not been customary to immobilize the neck externally, but if some pain returns postoperatively a removable head-neck-shoulder splint made of plaster of Paris or a well fitted neck brace is used for one to three months. When multiple levels have been fused it has become routine to immobilize the neck for three to six months. The more spaces fused, the longer and more complete the postoperative immobilization.

A continuous bone bridge from one vertebral body to another is seldom apparent by roentgenogram for six to nine months after surgery.

TABLE I

RESULTS OF ANTERIOR REMOVAL OF INTERVERTEBRAL DISCS AND FUSION IN THE CERVICAL SPINE

Case	Age (*Years*)	Sex	Bilateral Signs	Bilateral Symptoms	Discs Removed	Relief of Preoperative Complaints	Months After Surgery at Follow-Up
1. B. R.	39	M	×	×	1	Excellent	36
2. F. L.	43	M	×	×	1	Excellent	31
3. E. M.	35	F	×	×	2	Poor	28
4. M. H.	46	F	×		2	Excellent	27
5. L. P.	35	F		×	1	Fair	27
6. V. E.	38	F			2	Excellent	27
7. C. S.	50	M			2	Excellent	26
8. T. F.	35	F		×	3	Fair	25
9. W. L.	25	M		×	1	Excellent	24
10. C. N.	38	F			1	Excellent	20
11. M. G.	36	F			1	Excellent	20
12. J. R.	33	M	×	×	2	Good	16
13. C. S.	34	F			2	Good	16
14. B.W.	43	F	×	×	1	Excellent	15

RESULTS

The results are summarized in Tables I and II. The oldest patient in the series was fifty and the youngest was twenty-five years of age, the average age being thirty-eight years. All of the patients were white. Five of the patients were men and nine were women. Eight had bilateral symptoms and six had definite bilateral physical signs. The remainder had unilateral symptoms and signs.

Twenty-two intervertebral spaces were cleaned out anteriorly and filled with a bone graft by the anterior approach. Each disc removed was grossly degenerated. The levels operated on are shown for each patient in Table II; the fifth and sixth and sixth and seventh cervical intervertebral levels were most frequently involved.

The criteria for solid fusion were a solid bridge of bone visible roentgenographically between two vertebral bodies and lack of measurable motion in the two vertebral bodies on lateral roentgenograms made during flexion and extension of the cervical spine. Although motion might have been observable at the operative site, no fusion was considered solid until a continuous bone bridge could be seen on a lateral roentgenogram (Fig. 1-D). Thus of the twenty-two intervertebral discs operated upon, eighteen eventually showed a bone bridge, and twenty-one showed no motion on roentgenograms made at follow-up examinations. In other words, in three of twenty-one disc spaces a fibrous instead of an osseous union had occurred as seen on follow-up roentgenograms. The average period of follow-up was twenty-four months.

Two patients had a fair final result. One patient (Case 3, E. M.) had no apparent relief from the disc removal and interbody fusion; subsequently due to persistent bilateral symptoms and signs, foraminotomy at two levels was performed. These procedures were extensive; most of four facet joints at the levels of the fifth and sixth and sixth and seventh cervical vertebrae were removed. The results in this patient are fair since the final procedure, but the result of the anterior fusion alone was poor. However, extensive foraminotomy could not have been done as safely, in our opinion, unless there had been stability of the spine by the anterior fusion performed several months prior to laminectomy and excision of the posterior articulations. The other patient had a fair result after anterior fusion was repeated (Figs. 7-A and 7-B).

One patient had a good and not an excellent result although all of the arm and hand pain disappeared. A little discomfort in the neck was occasionally noted and the medial

TABLE II

CERVICAL INTERVERTEBRAL DISCS REMOVED IN FOURTEEN PATIENTS

Case	Third and Fourth	Fourth and Fifth	Fifth and Sixth	Sixth and Seventh	Seventh Cervical and First Thoracic	Total
1					×	1
2				×		1
3				×	×	2
4			×	×		2
5			×			1
6			×	×		2
7			×	×		2
8	×		×	×		3
9			×			1
10			×			1
11			×			1
12		×	×			2
13			×	×		2
14			×			1
Total	1	1	11	7	2	22

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 8. Lateral roentgenogram of the cervical spine made nine days after removal of intervertebral-disc material between the third and fourth, the fifth and sixth, and sixth and seventh cervical vertebrae. One can see that the interspace between the third and fourth vertebral bodies is blocked apart by a bone graft.

Fig. 7-B: Lateral roentgenogram of the cervical spine of the same patient made nine months after operation. A good bone bridge had formed between the third and fourth cervical vertebrae. However, the disc space had returned to its preoperative height and showed no widening as a result of surgery. There was a good bone bridge between the sixth and seventh cervical vertebrae with calcification under the anterior longitudinal ligament extending up in front of the sixth cervical vertebra. The interspace between the fifth and sixth cervical vertebrae failed to show any evidence of fusion. Re-operation was done at this level resulting in symptomatic improvement.

superior scapular tip was tender. Another patient has a good result, but in view of his preoperative problem, a few residual symptoms are not of great importance.

Nine of the fourteen patients were completely relieved of their preoperative pain by this operation alone and are considered to have excellent results. Thirteen of the fourteen were improved. One was not improved by this operation alone.

An interesting observation was that the neck and occipital pain was usually relieved immediately and that the arm pain disappeared within a few days following surgery and did not return. However, one patient continued to complain for nine months until the fusion at two levels became solid as seen by roentgenogram after which he was pain-free for two years. No external immobilization was used postoperatively for this patient.

COMPLICATIONS

Two patients had Horner's syndrome, one lasting about one week and the other about six months; two had paralysis of a vocal cord, one clearing in about three weeks and the other between the sixth and ninth postoperative month; one patient had postoperative tracheitis requiring steam inhalations for five days; and in one patient the vertebral artery was perforated without sequelae.

After this series was finished the pharynx of one patient was perforated just above the glottis. In that instance the pharynx was repaired and operation on the cervical spine was delayed six weeks. The esophagus healed properly without sequelae.

No wound infections occurred. In the description of the operation the technical modification which we have found best for avoiding each of these technical complications has been noted.

CASE HISTORIES

Case 3. E. M., a white housewife and secretary, thirty-five years old, reported no trauma in connection with the neck. Previous spine surgery had consisted in an exploration at the lumbosacral joint with disc removal and fusion in 1949. Cervical symptoms began two years prior to hospital admission during which time the patient had had non-surgical treatment for the cervical pain. Prior to operation she had numbness of the right ring finger and weakness of the grip in the right hand. She had noticed intermittent muscle twitching in the upper and lower portions of both arms, and complained of interscapular pain with the recurrent episodes of pain in the neck and arms. Prior to the intervertebral-disc removal and fusion there was hypaesthesia over the distribution of the eighth cervical-nerve root and diminished reflex of the biceps and triceps brachii on the right as compared with that on the left. There was interspinous tenderness between the sixth and seventh cervical vertebrae posteriorly and on prolonged extension of the neck, pain in both arms and hands was reproduced.

Lateral roentgenograms showed that the interspace between the fifth and sixth cervical vertebrae was very slightly narrowed. The fifth, sixth, and seventh cervical vertebrae and the first thoracic vertebra tended to remain in a neutral fixed position during flexion or attempted flexion of the neck. At the same time, above the fifth cervical vertebra flexion occurred. No remarkable spurs were seen in the oblique roentgenograms of the cervical spine. Discogram showed an abnormal pattern of a filling defect and degeneration at the fifth and sixth, and sixth and seventh cervical vertebral interspaces and at that between the seventh cervical and first thoracic vertebrae. However, the patient's pain was reproduced only at the lower two interspaces. Therefore, on October 8, 1954, intervertebral-disc removal and interbody fusion was performed from the right side at the sixth and seventh cervical vertebral interspace and at that between the seventh cervical and first thoracic vertebrae, in view of the fact that her clinical symptoms and signs were best correlated with nerve-root compression or irritation at these two levels. Postoperatively the patient was improved and muscle fibrillations that she had noted disappeared, but she still had pain into both shoulder areas and into the right hand upon extension of the neck. She continued to complain that she had pain in the neck and arms running to the ring and little fingers of both hands. The consensus of several examiners was that there was no improvement after the disc removal and fusion and the result was classified as *poor*, twenty-eight months after surgery.

Stabilization of the neck at the sixth and seventh cervical and the seventh cervical and first thoracic interspaces resulted, however, from the anterior-fusion procedure. On July 16, 1955, after this stability had been gained, a multiple foraminotomy including partial bilateral excision of the posterior articulations at the sixth and seventh cervical and seventh cervical and first thoracic levels was performed, ten months after the first operation. Following the second operation there were no complications. Neck extension was not

accompanied by severe pain into the shoulders and arms as before the second procedure. The patient returned to work for the first time in several years and when re-examined twenty-eight months after the original procedure and eighteen months after the secondary laminectomy and foraminotomy, her symptoms and signs involving the right arm were relieved, and she complained only of "aching muscle tiredness" in the left shoulder and arm. The over-all result from both procedures was classified *fair*. She not only returned to doing her own housework but was working as a part-time secretary (Figs. 2-A and 2-B).

CASE 4. M. H., a white housewife, forty-six years old, reported no trauma specifically related to the neck. One year prior to disc removal and interbody fusion the patient had had a foraminotomy on the left side at the fifth and sixth cervical vertebral interspace which involved complete excision of the posterior articulations. The patient had severe recurrence of her symptoms four months prior to the second procedure which had not been relieved by non-surgical treatment.

The patient had had a gradual onset of pain, first in the left shoulder and arm, about 1952. Four months prior to surgery she had had a severe recurrence of pain which had not responded to extensive non-surgical therapy. Preoperatively her symptoms consisted of pain in the neck and right shoulder, pain in the right arm and hand, and numbness in the right arm and in the thumb, index, and middle fingers. The neck pain included interscapular pain. There was a positive extension test of the neck reproducing pain into the right arm and hand. When in extension the neck was rotated, acute pain in the right arm was produced. The periosteal radial reflex was diminished on the right. There was weakness of the extensor tendons of the right hand and elbow.

Roentgenograms showed that at a previous operation on the cervical spine excision of the posterior articulations on the left had been performed at the fifth and sixth cervical vertebral interspace. There was disc narrowing and spur formation at the interspaces between the fifth and sixth and sixth and seventh cervical vertebrae bilaterally. The spurs were both posterior and posterolateral. Discogram showed abnormal outline and injection of the contrast medium produced pain at both the fifth and sixth and sixth and seventh cervical vertebral interspaces. On November 4, 1954, intervertebral-disc removal and interbody fusion was performed from the right side at the fifth and sixth and sixth and seventh cervical vertebral interspaces. Postoperatively, the abnormal physical findings rapidly disappeared and there were no residual complaints four months postoperatively. The patient was working without complaints twenty-seven months postoperatively. The result is considered *excellent*.

CASE 7. C. S., a white contractor and builder, fifty years old, stated that he had been severely mauled in a labor dispute in 1939. For twelve years the neck, shoulder, and arm pain was intermittent but the attacks became more frequent and more prolonged until they were almost constant by 1952. Various forms of non-operative treatment had been employed by various physicians for one and one-half years prior to surgery without any relief of symptoms.

On physical examination prior to surgery there was obvious spontaneous muscle twitching in the right forearm in the region of the extensor muscles of the hand and fingers which could be increased by prolonged extension of the neck. Extension of the neck also produced pain at a point behind the medial superior tip of the right scapula which proceeded down the posterior edge of the deltoideus muscle, then along the radial groove to the elbow, and along the extensor surface of the elbow to the thumb and index finger. There was tenderness of the radial nerve. There was pain and tenderness on the anterior aspect of the elbow and over the extensor muscles on the right arm down to the wrist. There was paraesthesia over the thumb and index finger. There was partial paralysis of the sixth cervical-nerve root noted by absence of the periosteal radial reflex and the reflex of the left biceps brachii with partial loss of pain and touch sensation over the thumb and index finger and the lower radial side of the forearm.

Roentgenograms showed moderate narrowing of the fifth and sixth cervical intervertebral space and slight narrowing at the sixth and seventh cervical vertebral interspace with spur formation posterolaterally into the intervertebral foramen on the right side at the fifth and sixth cervical vertebral interspace. Injection of contrast medium at both the fifth and sixth and sixth and seventh cervical vertebral interspaces produced pain and the discogram showed an abnormal pattern.

On December 3, 1954, intervertebral-disc removal and interbody fusion at the fifth and sixth and sixth and seventh cervical vertebral interspaces was performed from the right side. Postoperatively there was a Horner's syndrome and temporary paralysis of the right vocal cord. These complications completely disappeared in nine months. When reviewed twenty-six months postoperatively, the patient showed only a slight residual weakness of the triceps brachii muscle but all other symptoms and signs had gradually regressed in the one year following surgery. The result was considered *excellent* (Figs. 5-A and 5-B).

CASE 8. T. F., a white female nurse, thirty-five years old, reported that a fall on a hard floor in a sitting position in 1947 caused neck symptoms. The patient stated that symptoms in the neck, shoulders, and arm continued despite two operations on the neck on the left side which had consisted of seven foraminotomies. Prior to surgery in January 1955 she complained of pain in the left shoulder, index finger of the left hand,

and weakness in the grip of the left hand. There was pain in the neck, particularly on the left side. All of these symptoms had failed to respond to non-operative therapy and surgery over the previous five years.

On physical examination the patient showed hypaesthesia over the left thumb, the index and middle finger. The extension test of the neck was positive and reproduced pain into the left shoulder and down the left arm into the left index finger. Flexion of the neck reproduced the pain in the left shoulder.

Discograms were made at each interspace between the third and the seventh cervical vertebrae. It was difficult in this patient to interpret the pain distribution with the injection of contrast medium but the pain seemed to be duplicated when injection was done at the third and fourth, the fifth and sixth, and the sixth and seventh cervical vertebral interspaces. The spine was straighter than normal in the lateral view. There was roentgenographic evidence on the plain films of foraminotomy at each interspace between the third and the seventh cervical vertebrae. At three of these levels the foraminotomy was bilateral and at one level, unilateral. No large spur formation was seen. There seemed to be some narrowing at the interspaces between the fifth and sixth and the sixth and seventh cervical vertebrae.

On January 11, 1955, intervertebral-disc removal and interbody fusion at the third and fourth, the fifth and sixth, and the sixth and seventh cervical vertebral interspaces was performed from the left side. Postoperatively, this patient had severe tracheitis for five days which was believed due to sensitivity to the intertracheal tubing used for intubation anaesthesia. It should be noted that a similar complication followed a thyroidectomy on this patient several years previously. The second complication was the development of a keloid. Postoperatively the patient complained of pain in the lumbar spine as well as in the neck. She had had multiple operations previously in the area of the cervical spine and one exploration in the area of the lumbar spine. Physical findings were unchanged from the preoperative state and therefore after ten months the result was classified as *poor*.

Approximately eleven months after the procedure of January 11, 1955, the patient was re-operated upon in her home area and the fifth and sixth intervertebral level of the cervical spine was found to be movable and was re-fused *via* the anterior approach. Roentgenograms and operative exploration showed bone fusion at the third and fourth and sixth and seventh cervical intervertebral levels. The total result of these procedures was not reviewed by the authors but the patient was reported improved by her attending surgeon. The total result from disc removal and interbody fusion is listed as *fair* twenty-five months after the secondary vertebral-body fusion (Figs. 7-A and 7-B).

Case 13. C. S., a white female beautician, thirty-four years old, stated that she had had neck injury in an automobile accident about eight months before surgery. For the past seven months there had been persistent pain in the neck and left arm and weakness, particularly partial weakness in the grip of the left hand despite non-surgical therapy with a collar and traction. Preoperatively the patient complained of pain in the neck, the left shoulder, the left hand, and numbness in the left shoulder, arm, and hand with suboccipital headaches. There was tenderness posteriorly over the neck between the fifth and sixth vertebrae in the mid-line. The extension test of the neck was positive and rotation of the chin to the right gave severe pain into the left arm and down to the index finger and the thumb. There was tenderness of the radial nerve and diminution of the radial styloid reflex. A myelogram made prior to surgery was negative and roentgenograms were not remarkable except for perhaps a slight straightening of the neck in the lateral view. Injection of contrast medium at the fifth and sixth and sixth and seventh cervical vertebral interspaces caused reproduction of the pain in the arm and the discogram showed a pattern typical of disc degeneration.

Operation was performed on October 27, 1955, when intervertebral-disc removal and interbody fusion at the fifth and sixth and sixth and seventh cervical vertebral interspaces was performed from the left side. There were no postoperative complications. The preoperative findings disappeared except for some tenderness and mild discomfort over the superior medial tip of the left scapula and very occasional aching in the neck. Sixteen months after the disc removal and fusion the patient considered that she was at least 75 per cent improved. An independent examiner judged that the patient had perhaps 15 per cent of residual disability in the neck. The final result is considered *good* (Figs. 4-A and 4-B).

Case 14. B. W., a white housewife, forty-three years old, gave no definite history of trauma in relation to the neck. Removal of intervertebral-disc material at the fifth lumbar and first sacral interspace and spine fusion at that level had been performed in 1953. Results of that operation were excellent.

At the onset the pain was gradual and intermittent, involving the neck, both shoulders, arms, hands, the fingers, and the interscapular area for eight years. The intermittent attacks had become more frequent and more prolonged so that in the year prior to surgery the discomfort had been practically continuous and accompanied by numbness in the right thumb with pain in the right anterior portion of the chest. Extensive conservative therapy, such as collars and traction, had failed. On examination there was a decreased biceps brachii reflex on the right and an absent periosteal radial reflex and biceps reflex on the left. The extension and rotation test of the neck reproduced the neck pain and that radiating into the right arm. There was on such tests some discomfort into the left shoulder and arm. On testing there was some weakness of the grip in the right hand. Roentgenogram showed definite narrowing of the fifth and sixth cervical vertebral inter-

space and discogram at this level showed a positive pattern and injection of contrast medium reproduced the patient's pain distribution. On November 15, 1955, intervertebral-disc removal was performed followed by interbody fusion at the fifth and sixth cervical vertebral interspace. In this case bone-bank bone (frozen bone from the rib) was used. Postoperatively the patient had no complications. The preoperative findings disappeared. She resumed full activity without complaint and when evaluated fifteen months postoperatively the result was considered *excellent* (Fig. 2-C).

DISCUSSION

Four of the patients in this particular series had had previous thyroid surgery. This series, as well as other patients with discogenic disease who have had previous thyroid surgery, strongly suggested to us the possible importance of a metabolic factor in intervertebral-disc disease.

A degenerated intervertebral disc can apparently create abnormal mechanics in the cervical spine even before roentgenograms show significant intervertebral-space narrowing or remarkable spur formation. From such a level shoulder, neck, occipital, and even arm pain may arise. The localizing signs may not be clear in these patients on physical examination. However, a discogram at the involved level should give a roentgenographic pattern typical of disc degeneration (Figs. 2-A, 2-B, and 2-C) and the pain which forms the chief complaint may be reproduced during the discographic procedure. Pain arising during discography may occasionally be so diffuse that the patient will have difficulty associating it with the pain which he originally had. Critical analysis of this pain reduplication during discography depends in large measure on the patient's emotional stability and the surgeon's experience with the procedure. However, the contrast medium flows with little resistance into a degenerated disc whereas into a normal disc only a small amount can be inserted and that only under great pressure. The discogram shows an abnormal pattern: instead of a neat lense-shaped outline of a normal cervical nucleus pulposus, an irregular extension of the contrast medium beyond the central nucleus occurs across the disc space to the region of the joints of Luschka and into the area of the intervertebral foramina. In the lateral view the contrast medium usually proceeds out of the disc space up and down under the posterior longitudinal ligament (Figs. 2-A, 2-B, and 2-C) when the disc is degenerated.

When true disc protrusion or large posterior osteophytes cause compression of the cord and evoke long-tract signs, posterior decompression of the spinal cord and possibly section of the dentate ligaments appears indicated [18, 23]. In those patients with long-tract signs a myelogram is indicated prior to such surgery. It is possible that in such situations spine fusion by the anterior approach may, by stabilizing the osteo-arthritic portion of the spine, decrease soft-tissue swelling over large posteriorly protruding osteophytes, or stop any irritation of the cord or of the anterior spinal artery, or of both, which may occur secondarily to osteophyte motion. However, the authors have used anterior spine fusion only once for such a situation. In that patient (Case 12, J. R.) spinal-cord irritation existed only intermittently and in mild degree. However, the patient's symptoms were relieved clinically by the anterior cervical-spine fusion at two levels.

Spurs on the superior element of the posterior cervical articulations and on the joints of Luschka are reported to cause intermittent or continuous pressure on the vertebral artery with spasm of the artery in some instances [7, 10]. Possibly they may also irritate or compress the posterior sympathetic plexus which accompanies the vertebral artery [1, 17]. This condition may eventually have to be differentiated from Ménière's syndrome and may possibly give rise to syncopal attacks although such a clinical syndrome is not as yet clearly defined [17]. So far the operation described has not been used primarily for this condition but it would appear to be indicated in such a situation if the exact level of vertebral-artery irritation can be precisely localized.

Originally we hoped that after cleaning out the intervertebral-disc material through the anterior approach it would be possible to wedge the vertebral bodies apart and that

this would also increase the diameter of the intervertebral foramina (Fig. 3). Actually, however, opening up the interbody space may tend to extend the cervical spine, a position which causes pain in many patients having constriction of the intervertebral foramina by osteophytes. Extension alone does not effectively enlarge the intervertebral foramen. Furthermore, the bone graft is largely resorbed and remodeled. Even though it originally acts as a conductor of osteoblasts between the two vertebral bodies it eventually ceases to exist as an effective mechanical strut for separating the two vertebral bodies. Therefore, in late postoperative roentgenograms the two vertebral bodies that were propped apart at the operating table by the bone plug have either returned to their preoperative position in relation to each other or the space between them has become narrower than it was preoperatively.

CONCLUSIONS

1. Disc degeneration in the cervical spine usually associated with osteo-arthritic changes is a cause of nerve-root irritation and compression giving rise to occipital and hemicranial headaches, pain in the neck, shoulder, between the scapulae, in the anterior portion of the chest, and in the arm and hand. Instability of a cervical vertebra can also cause similar pain.

2. The cervical-spine level from which such pains arise when exactly localized can be fused after excising the disc by placing a bone graft anteriorly between the vertebral bodies. Such a fusion appears to stop the pain.

3. This method of treatment without serious complication has completely relieved the discomfort of nine of fourteen patients and caused improvement in four others. Conservative therapy and other surgical attempts had failed to relieve the discomfort of these patients prior to the disc removal and interbody fusion.

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DISCUSSION

Dr. J. E. M. Thomson, Lincoln, Nebraska: This presentation is timely and commendable in that it brings us closer to understanding one of the most confusing and illusive pain syndromes. The authors thoroughly covered the numerous etiological potentialities which cause local symptoms in the neck as well as those referred to the chest, back, and upper extremities. They correctly emphasized the importance of definite adequate diagnosis of the particular pathological conditions involved and its relative importance in connection with the effective conservative or surgical treatment.

The exposure of the anterior portion of the bodies of the cervical vertebrae has been ably demonstrated by Dr. Southwick and Dr. Robinson[a]. The method is intriguing but it seems to demand a very skilled and experienced hand. The transitory complications of two Horner's syndromes, two instances of paralysis of the vocal cords, one instance of tracheitis, one vertebral artery perforated, and then a ruptured esophagus in a later case forms a formidable group.

It is gratifying that the authors tried their technique on eight dogs before turning to human beings. We have not got beyond canine investigation, either from an operative or a discographic standpoint.

In the patient, E. M. (Case 3), the result of the disc removal and interbody fusion was poor and extensive bilateral foraminotomies at two intervertebral levels were later performed with fair results. In this case, one can agree with the authors' opinion that the subsequent extensive foraminotomies could not have been done as safely as they were without the stability afforded by the preceding fusion. Hence, although the result of anterior fusion itself was poor, it nevertheless made possible a subsequent procedure which improved the result.

The authors' comments concerning the attempts to force the vertebrae apart in order to enlarge the intervertebral foramina were interesting. The osteoclastic activity, invariably present, apparently has a flattening effect on the graft to the extent that ultimately the intervertebral space could be less than that before surgery. Therefore the assuring feature of this method after all is the fusion.

Dr. Smith and Dr. Robinson should be commended for their courageous approach to this problem. Their results indicate the importance of this method of treatment in a selected group of patients with cervical-disc nerve-root syndromes. If our specialty is to progress, we cannot afford to look askance at original approaches to difficult surgical problems and not add to our armamentarium those surgical techniques which, although unusual, have proved by experience to give a measure of good results.

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Dr. James Gordon Petrie, Montreal, Quebec, Canada: At the Montreal Neurological Institute and the Royal Victoria Hospital, Montreal, Dr. W. V. Cone and I have been much interested in this subject for many years in the treatment of trauma as well as in the treatment of neck pain with or without radiating pain.

We all know that skull traction in a young person will give some separation of the cervical vertebrae, but we have found that considerable traction, up to seventy-five pounds, as used occasionally with fracture-dislocation of the cervical spine, gives only minimal or no separation of the vertebrae at the level of an old degenerated disc, and in the adult, widening of the intervertebral disc at normal levels and under heavy traction is not marked. This raises the question as to how traction benefits some of these patients. Is it due to change of posture and relief of muscle spasm?

One point that should be stressed in the treatment of intervertebral lesions is that the operation is usually for pain, and therefore is one of election, and the simplest, safest procedure should be used. If muscle weakness is present then it should be considered an emergency. If fusion alone will relieve the pain we believe an articular-facet fusion along with parallel grafts is the shortest procedure. It is simple to fuse up to four

vertebrae together. As Abbott and others have shown, cancellous bone possesses a high osteogenetic power, whereas cortical bone pos- es strength but little osteogenetic power. We expect the articular facets to be well fused in two months, and the parallel cortical grafts to take a longer period of time to fuse.

We have had very little experience with discograms. We would not want to do them on normal discs, as Dr. Reuben Rabinovitch has shown with young animals (rabbits, dogs, and monkeys), using an eighteen-gauge needle, that disc material may be extruded from a normal disc following puncture. We do believe myelography is important, not so much in the diagnosis of a ruptured intervertebral disc, but rather to give us a clue as to the level of the involved disc or discs.

We believe the best indication for the anterior fusion is when a wide laminectomy, as far as the articular facets, has been carried out previously and there is increasing pain and deformity of the neck.

MAKING THE MILWAUKEE BRACE

(*Continued from page 528*)

A traction frame (Fig. 4) is fastened to the pelvic girdle to correct pelvic obliquity. Pins through the tibiae are incorporated in casts. Traction is made on the high side which has the short cast. A spring balance is interposed to measure the force. The leg on the low side with the toe-to-groin cast is pulled upward with heavy rubber bands in the back and front.

APPLYING THE BRACE

The brace is reassembled and put on the patient by the orthotist. It should be checked carefully by the orthopaedic surgeon. It should fit loosely with only slight corrective force. If the spine was considerably elongated during the application of the model, it will be necessary to shorten the brace one-half inch (1.27 centimeters) or more before applying it. No additional correction of the curve should be attempted until the skin is accustomed to the pressure of the brace. The patient should be able to raise his chin and occiput simultaneously from the head support, or rest the head on its support and shift the chest away from the lateral pressure pad. This situation must prevail at all times during and following the correction. The appearance of pressure areas is evidence that too much force is being used.

The brace should not be uncomfortable even when first worn. With the patient in the prone position, the pelvic girdle should be loosened and the skin of the entire torso given nursing care at least once a day for the first six weeks that the brace is worn. When the belt (Fig. 2, *B*) is to be fastened again, it is wise to pull on the patient's legs so that the girdle will fit snugly above the waist and not cause pressure on the lateral surfaces of the ilia. The gap between the posterior edges of the pelvic girdle must remain constant. As the belt stretches, it must be tightened further to maintain this position.

The chin must be capable of protrusion at any time. Pain at the temporomandibular joint or pain in the teeth means that the brace must be shortened. Vigorous distraction will obviously make pressure on the teeth. Rarely, in young children, protrusion of both upper and lower incisors has occurred. This protrusion has always receded rapidly upon removal of the brace at the completion of treatment. Permanent deformity has not occurred.

A marked overbite is a frequent finding in idiopathic scoliosis as noted by Chandler. Care should be taken to examine the jaws prior to the onset of treatment. If an abnormality exists, an orthodontist should be called in consultation and he should prepare a plaster mold of the teeth as a record. Mandibular deformities should not erroneously be ascribed to the brace. No change of bite has been observed with the use of the brace.

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The Management of the Burned Hand*

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Thermal burns of the hand may result in great disability and economic disaster for the victim. Although all treatment is directed toward decreasing disability the methods used to achieve success may differ widely. All surgeons wish to remove the dead tissue as quickly as possible to gain a surface on which a graft may be set. There is little agreement, however, in how this is to be done. All surgeons desire the return of normal function; some hope to gain this by very early movement, and others expect the same result by immobilizing the hands until they have healed.

At the Toronto General Hospital, the local treatment of the burned hand has evolved

FIG. 1-A

A local third-degree burn without an area of second-degree burn surrounding it. Suitable for primary excision and skin-grafting.

into an almost unvaried routine which we think is clearly superior to other methods of management. In the past ten years there have been over two hundred and fifty patients with burns. Among those, about fifty hands required treatment. It must also be noted that these burns are practically confined to the dorsum of the hand; a third-degree burn of the palm is very uncommon.

Whatever the merits may be of open treatment in other parts of the body [5], aided by an agent such as aluminum powder [3], this form of treatment has limited application in the hand. The local third-degree burn, not surrounded by an area of second-degree burn resulting from contact with a hot object, is the only kind of burn we might treat by the

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open method. In this case, after a day or two, the area will dry and the outlines of the necrotic skin will become sharply defined. A primary excision of the necrotic tissue covered by an immediate skin graft may be performed. Excision of burned tissue of the hand has its own dangers and would be performed only because of the limited area of an injury.

Any extensive burn of the hand is treated by the closed method. With any injury, immobilization is beneficial and should be maintained in the position of function. For this, the Chicago universal splint is ideal [1]. The original dressing should be simple. The hand is gently debrided and washed by profuse irrigation. Mechanical cleansing can be harmful.

FIG. 1-B

Photograph showing the result three months postoperatively. Full movement of the hand is shown, but the graft has become pigmented and the scars at the edge of the graft are poor.

Foreign material which adheres is better left. An attempt to remove it forcefully risks further damage. To avoid eschar, the hand is coated with petroleum jelly. One piece of flat gauze, four by four inches, is placed between the fingers to separate them. The palmar surface of the hand is then covered with a surgical dressing pad. These pads are large; eight inches wide, twenty-four inches long, and one-half inch thick. They are made of absorbent cotton covered by open-mesh gauze. One pad is sufficient to dress the palmar surface of the hand and another to cover the dorsal surface. The universal splint is placed in position outside the dressing and everything is enclosed in a bandage. We have found that the use of gauze or tulle gras next to a burned surface offers no benefit, and we therefore omit it.

After enclosing the hand, we feel that immobilization is desirable during the period of

greatest swelling and reaction. Changing dressings early to allow movements is painful, traumatic, and permits the entrance of bacteria. Early movement is harmful, since swelling and reaction increase, and may result in increased disability.

On the eleventh day, it is our practice to change the dressing for the first time under light anaesthesia in the operating room. All obviously necrotic tissue is removed with the surgeon taking care to remove only superficial tissue. If there is considerable discharge from the burned area, re-dressing is done with dry pads only. If, however, there is very little discharge and the burned areas are dry, a layer of petroleum jelly is applied and the dressing pads are moistened in saline before they are applied.

In another forty-eight hours, a similar débridement and change of dressing is performed under anaesthesia. The removal of the dressing helps the débridement since much

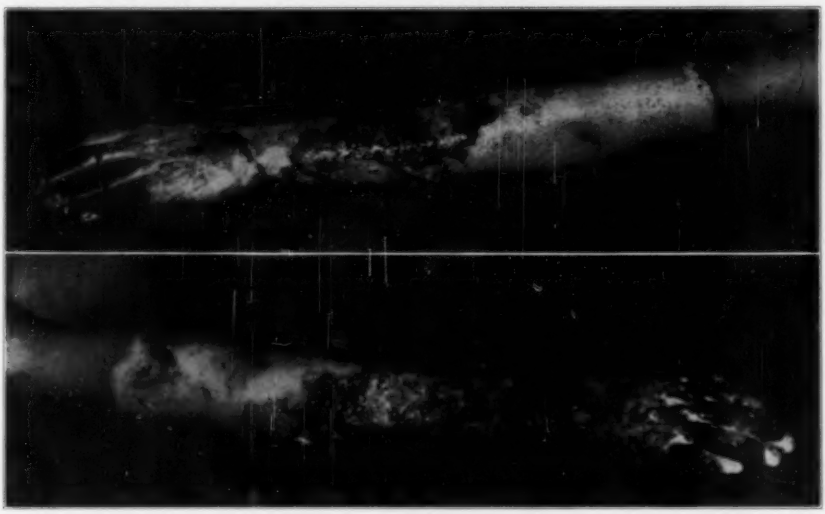

FIG. 2-A

Third-degree burns of both hands and forearms ready for skin-grafting on the eighteenth day.

of the necrotic material sticks to it as it is removed. Again, any adherent necrotic material is cut away and the hand is re-dressed with petroleum jelly and saline-moistened pads if the burn appears to be drying out; otherwise, if there is considerable discharge, it is dressed absolutely dry.

Four such dressings under anaesthesia are required before grafting can be performed. If the procedure is begun on the eleventh or twelfth day, grafting can be performed on the seventeenth or eighteenth day. By means of this method, we have been able to avoid changing dressings in the ward—a procedure which is painful and upsetting to the patient even under sedation. The patient is unafraid and cooperative because he has never been hurt by treatment [4].

This method of management was really evolved in our attempts to find a way to treat burns without upsetting the patient. During our early experiments, we found that burned hands could be treated this way by the eighteenth day and that graft beds so prepared were particularly receptive to grafts. There have been no instances in which the graft did not fully take.

What we are doing is multiple débridement and not excision. The grafts can be placed on tissue which is just beginning to granulate and which will maintain the characteristics of subcutaneous tissue in the future. Multiple débridement seems to be more tedious than radical excision in one stage; however, it is much safer since no risks have been taken in

needlessly exposing tendons or joints. We have found that an exposed tendon or open joint is disastrous to the future function of the digit.

By the eighteenth day, the patient has had four dressings with débridement under light general anaesthesia and is ready for skin-grafting. At operation, the removal of the dry adherent dressings reveals a red, gently bleeding but not oedematous surface. This is an excellent surface for grafting, and the time is opportune. An attempt to graft too soon,

FIG. 2-B

Full movement of all fingers is shown six weeks after injury (three weeks postoperatively). The white areas were the second-degree burns, and the dark areas were the grafted areas of third-degree burns.

before all the necrotic material is removed, will result in a poor take. Delay, when one must wait for daily dressings to provide a clean surface, is equally undesirable. We have found that discharges from the burned areas become more profuse and take on the characteristics of pus after approximately twenty-one days, making success in skin-grafting less certain. An almost perfect graft take can be expected when it is applied about the eighteenth day.

We have favored a very thin skin graft, approximately ten one-thousandths of an

FIG. 3-A

Strips of skin between eight and ten one-thousandths of an inch thick have been taken with the electric dermatome and applied on the eighteenth day.

FIG. 3-B

Photographs showing the results three months later. During the following six months these grafts became thick and lumpy.

inch. The electric dermatome is excellent for obtaining this type of graft. The grafts are applied to the hand without sutures, and then the hand is dressed in the universal splint. Five days later the dressings are removed.

When the swelling is gone and there is no pain (that is, after the open areas have been covered), the dressing can be removed without distress. When the outer bandages are taken off and the splint is removed, the whole hand with the dressing pads in place is immersed in a hand bath of warm water or saline. The dressings float off without trouble and the patient is encouraged to begin movements of the fingers. Because he has never been frightened or hurt by frequent dressings before grafting, he is confident and cooperative. Movement is at first very gentle and is only that which the patient can accomplish himself. The

FIG. 3-C

Result three months after removing the early skin graft and resurfacing with a thicker graft. The normal hand is shown for purposes of comparison.

hand is left out in the air or in a warm water bath, depending on the suppleness of the fingers. After an hour or so the hand is re-dressed and the splint is reapplied until the next day. The same procedure is carried out the following day, once in the morning and once in the afternoon.

If the patient had a full range of motion at this stage, it is likely that the graft would be damaged. However, since there has been so much limitation of movement, this has not happened in any of our cases. The time taken for the range of motion to increase allows the grafts to become firmly settled. The periods spent out of dressing and splint are increased fairly rapidly, and by the end of a week no further dressings are used.

Physical therapy, at this stage, is accomplished by the patient himself following the instructions given by the surgeon. Anything vigorous, besides harming the grafts, can increase stiffness because of trauma. Later on a more formal program may be adopted, but it is often unnecessary since movement returns quickly without it.

These remarks refer to common extensive burns of the hand, those almost wholly confined to the dorsum with only small patches of destruction on the palm.

The deep burn of the hand, in which a tendon is burned and a joint capsule is involved, may appear at first much more benign than it really is. However, this injury should be treated conservatively, just as the less severe burn. In this kind of injury, any attempt at early excision may lead to disaster. In fourteen to eighteen days, the extent of the damage is more readily apparent; then excision of the gangrenous portions of the finger with immediate repair by grafting may be undertaken if necessary.

RESULTS

This regimen not only allows reasonably early grafting, but usually results in excellent skin covering. The junction between graft and normal skin is smooth and is not outlined by an hypertrophied scar. The grafts, being very thin, do not contract. In our

FIG. 4-A

Volkmann's ischaemic contracture of the intrinsic muscles of the hand, three months after skin-grafting. Note the typical deformity.

group of patients there has not been one in whom there was contracture resulting in an important restriction of flexion. We have had three patients, however, in whom the grafts became thick and lumpy with the intermittent appearance of fissures over the joints. These were treated at the end of six months by complete excision of the skin of the dorsum of the hand and fingers, with resurfacing by a dermatome graft of approximately eighteen one-thousandths of an inch. Since these hands had excellent recovery of motion by the time this operation was performed, there was almost no stiffness when the dressings were removed at the end of ten days. These grafts, being thicker, require longer immobilization in the position of function than is necessary for the very thin grafts used in the primary grafting. The result of this secondary operation has been so good that it is difficult to tell that the hand has ever been burned.

It is difficult to compare the rate of the return of motion of the fingers following different kinds of treatment. The injury itself varies from patient to patient, and the result is influenced by the physiological reaction of the patient to the injury. On the average our patients have recovered full motion of the fingers in about three months. That is not to say that there are not some who never regain full motion. There are also many who continue to improve after three months have passed, and gain excellent motion later.

COMPLICATIONS

Complications have been rare. The only complication has been Volkmann's ischaemic contracture of the intrinsic muscles of the hand [2]. This is worth special notice because the desirability of the closed method of treatment has been stressed. Although the use of pressure is not considered necessary in the closed method, the effect of pressure in the production of this condition cannot be dismissed. We believe that pressure is due to swelling taking place deep within the hand itself where distention cannot relieve it and that the dressing is not at fault.

FIG. 4-B

There is an increase in the range of motion after division of the interosseous tendons.

This complication occurred once. It was treated by division of the interosseous tendons through a longitudinal incision over the proximal phalanx which provided an excellent approach to these structures on each side.

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The Surgical Reconstruction of the Upper Extremity Paralyzed by Poliomyelitis *

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The problem of surgical reconstruction of the upper extremity paralyzed by poliomyelitis is best divided into two categories: basic principles and specific surgical procedures.

BASIC PRINCIPLES

In this category we are confronted with several problems of treatment to which consideration must be given, the over-all gain sought for the patient being of primary importance. The function remaining to the individual will determine the plan for the projected goal. Some patients can be expected to gain only in self-care activities; others with less general involvement may perform heavy labor following a surgical procedure. Isolated paralysis amenable to surgical treatment is not the rule, although it certainly does occur. A wide middle ground of improvement is the usual goal. It must be clear that the gain from the proposed procedure will not be offset by an important loss, that muscles or functions important to the patient will not be sacrificed without compensatory benefit.

Before an adequate plan for any patient can be devised, the surgeon should be cognizant of those motions which need to be replaced and of their relative functional importance. It is our present habit to think in terms of motion to be regained rather than of the muscles paralyzed by disease.

Those motions important in upper-extremity function are grasp or some part thereof, wrist motion or stability, pronation and supination, elbow flexion and extension or stability, humeral internal and external rotation, and humeral forward flexion. Scapulothoracic rotation and trunk stability are important in that they effect humeral placement. Stability (active muscle power or static positioning) is essential for all upper-extremity activities. It is of the greatest importance proximally, and as its importance decreases distally, the importance of mobility increases. The effectiveness of a mobile hand depends on proximal stability. After evaluation of the specific problem presented on examination, it must be decided whether the patient has sufficient muscle power to provide the desired functional effects of stability and motion.

There will be many instances when the decision will necessarily be against mobilization of a given joint and in favor of stabilization by tenodesis, bone block, or arthrodesis. By such stabilization, existing muscles may work more efficiently or, building on this stable base, other joints may be mobilized with increasing effectiveness. Contracture is almost never overcome through the power afforded by muscle transference. If joint contracture exists in the range to be converted from passive to active motion, this contracture should be relieved prior to any attempt at mobilization.

When the decision to try for an effective joint mobilization by muscle transference has been made, these points must be kept in mind if useful function is expected:

1. The muscle chosen as the motor must be of sufficient size and strength to provide adequate work output for the accomplishment of the functional task proposed for it. If it

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is ineffective in its normal position, it can be expected to be even less effective in a new location.

2. The musculotendinous unit must be transferred so that it may work in a straight line or through a free-gliding pulley system. Pulleys are effective for a few transfers, but in general they increase the friction in the system.

3. A muscle should never be moved from a site where it is essential to body mechanics without making adequate provision for its loss (for example, the wrist should be fused when wrist extensors are substituted for finger flexors). If such provision cannot be made, the procedure should be abandoned.

4. Secure attachment of the transferred muscle in its new location is essential. The new attachment should be to bone if possible, although in the upper extremity where forces are not so great as in the lower extremity, attachment may successfully be made to tendon or dense unyielding fascia.

5. Adequate postoperative care and fixation must be provided for the specific transfer. Each procedure will make certain specific demands for immobilization and for function to be resumed as early as it can be carried out safely.

6. The musculotendinous unit must be placed under sufficient tension. In practice this is about 80 per cent of the elasticity of the muscle with the joint in the corrected position. It should be noted that this is quite snug or tight.

7. A muscle chosen for a new task should have a muscle-fiber length which will permit a desirable range of motion in its new location. This muscle-fiber length will be directly proportional to the range of motion which the muscle had in its normal site.

8. The neurovascular bundle must not be damaged by kinking or by stretching. Occasionally, temporary nerve injury will result from stretching in complete muscle transposition; complete or partial recovery will occur in three to four months. However, if the damage to the nerve has been severe or if the arteriovenous system is seriously impaired, the transferred muscle will be unable to function.

9. A muscle should never be expected to have two separate functions; one should not expect one-half of a muscle to maintain a previous function and the other half to supply a new and separate function.

A little-explored method that warrants serious consideration is the combination of surgical reconstruction and arm bracing. Here the choices will, in general, be for gains within the limits of self-care and daily habits and great care must be taken to choose patients carefully with reference to their tolerance for appliances. However, with counteraction of gravity, or with slight brace supplementation and proper arm bracing, a weak muscle may be sufficient to be of use to the patient. For instance, an arm brace used to nullify the weight of the forearm may allow effective elbow flexion following an insufficient sternocleidomastoid transplant or minor hand reconstruction, which is of doubtful value without arm bracing, can provide movement through a satisfactory working range when the arm is stabilized. Often an improvement of scapulohumeral, scapulothoracic, or elbow muscle power may allow effective use of a Handy Hook.

SPECIFIC PROCEDURES

For greater clarity of presentation these will be discussed insofar as possible within the categories of function previously mentioned.

Grasp, or Some Portion Thereof

Thumb and finger flexion are essential to grasp and can be regained by the substitution of wrist muscles in any combination. When wrist flexors are used, wrist stabilization usually is unnecessary. Although wrist motion is not generally essential, its preservation is desirable if possible. If no wrist extensors are active and wrist flexors are to be substituted for finger flexors, arthrodesis of the wrist will be necessary for effective use of the trans-

plant. This procedure will provide a stable segment across which the finger flexors may work. When all of the wrist extensors are to be substituted for finger flexors, then wrist arthrodesis is advisable. Finger extensors alone are not strong enough to provide adequate wrist stability, and hyperextension of the metacarpophalangeal joints will occur. When possible, we transfer the extensor carpi radialis longus to the flexor pollicis longus, and the extensor carpi radialis brevis to the index-finger portion of the flexor digitorum profundus. The extensor carpi ulnaris is then transferred into the flexor digitorum profundus of the middle, ring, and little fingers. The brachioradialis will provide good finger flexion, but since it has a limited range of excursion, the range of finger function will lie within the middle range of joint function. If the extensor carpi radialis longus transference to the thumb flexor is unopposed by an extensor pollicis longus, flexion contracture of the terminal joint of the thumb frequently will develop. This may necessitate fusion of the interphalangeal joint of the thumb at 145 degrees of flexion. When finger flexors are paralyzed by poliomyelitis, wrist flexors are usually paralyzed also. However, if spared by the disease, there is no reason that they cannot be used for thumb or finger flexion. If no wrist or finger muscles are active, the biceps brachii may be used as a finger flexor. This can be done by means of a free tendon graft or by the use of inactive wrist flexor tendons as a bridge from the biceps brachii tendon to the flexor digitorum profundus tendons. In our opinion this is a very satisfactory procedure, provided the wrist is fused and the triceps brachii strong. Occasionally, in the absence of a suitable triceps brachii a biceps brachii transfer can be trained to work against the loads being handled. Here the load, together with gravity, takes the place of active elbow extension. In general, however, this is not satisfactory. Flexor tenodesis, by fixation of the flexor digitorum profundus tendons to the radius and with activation by wrist extensors, will also provide good finger closure. This is an alternate method to secure the function of grasp without transference of wrist extensors. Irwin feels that this is a particularly effective procedure. He may plan for use of one wrist extensor for finger extension, leaving the others to act as wrist extensors with his tenodesis.

Occasionally poliomyelitis results in clawing of the fingers with extension contracture of the metacarpophalangeal joints, effectively blocking weak flexor-muscle action from the fingers. Capsulectomy of the metacarpophalangeal joints with relief of the contracture of these joints may allow satisfactory finger flexors again to provide a useful range of flexion. Occasionally, arthrodesis of the metacarpophalangeal or proximal interphalangeal joints may be helpful in providing the fingers with useful function.

Extension of the thumb and fingers is not so important as flexion, but it should be provided whenever possible. For this purpose wrist flexors, wrist extensors, or the brachioradialis can be used. We do not anticipate the need for wrist arthrodesis when wrist flexors are transferred dorsally. Often the flexor carpi radialis was used for thumb extension, the palmaris longus for index-finger extension, and the flexor carpi ulnaris for extensor power to the middle, ring, and little fingers. The brachioradialis can be used for this purpose as well, but it is not the first choice. Finger extension can also be provided by transfer of a flexor digitorum sublimis tendon after the method of Irwin. As he pointed out, since much less strength is required for functional finger extension than for functional finger flexion, extension often may be restored with little sacrifice of flexion. The triceps brachii can be extended to the finger extensors in much the same way that the biceps brachii is to the finger flexors. This, however, has not proved an effective procedure in our hands. When there is loss of interosseus-muscle function, but satisfactory flexor digitorum sublimis and profundus function remains, Bunnell's technique for transplantation of the tendons of the flexor digitorum sublimis into the extensor aponeurosis expansions has given very satisfactory results.

Adequate grasp is greatly enhanced by three basic thumb motions. These are thumb abduction and extension, and opposition. Either thumb abduction or extension, or both,

allows the thumb to be carried away from the palm so that objects of varying size may be accepted by the hand. This function, as before noted, may be improved by the substitution of wrist flexors, wrist extensors, the brachioradialis, the extensor indicis proprius, or the flexor digitorum sublimis.

Opposition is important to thumb and finger function, and every effort should be made to provide it. Optimum restoration is to be sought but pinch between the tip of the opposed thumb and other fingers is not as useful as pinch between the tip of the thumb and the side of the index finger. Our favorite procedure for replacement of this function is to transfer the flexor digitorum sublimis of the ring finger either around the flexor carpi ulnaris tendon at the wrist or through a pulley made of half of the tendon sutured on itself at the pisiform bone. The distal end of the tendon is then led to the dorsal ulnar surface of the distal end of the first metacarpal bone and base of the proximal phalanx of the thumb. Many other procedures have been devised to supply this function, including the use of the wrist flexors or another portion of the flexor digitorum sublimis. When other muscles are not suitable, one may follow Steindler's use of the split flexor pollicis longus tendon. Whatever the procedure, the final result will be better if the first dorsal interosseus is active or, if not, has been replaced by transplantation. A flexor digitorum sublimis tendon or the extensor indicis proprius may be used for this transfer. This will allow better positioning of the index finger and provide counterpressure against which the thumb may work. If the available muscles are inadequate, the thumb may be fused in opposition. This can be accomplished either by a bridge between the first and second metacarpal bones, or by fusion of the base of the first metacarpal bone to the greater multangular bone and thence to the navicular bone. Muscles for replacement of hand function may be limited; on occasion every available possibility must be utilized. The principle of accepting any available muscle for use in hand reconstruction is demonstrated in the following case:

N. Y., a twenty-one-year-old poliomyelitic patient had been severely paralyzed three years prior to surgical intervention. In his left hand and wrist he had only weak flexor digitorum profundus function in the middle, ring, and little fingers. The thumb and index flexors were paralyzed. He had active thumb and finger extensors, but inactive opponens pollicis, wrist extensors and flexors except for a trace of function in the flexor carpi ulnaris. The brachioradialis and interossei were paralyzed. The patient himself called attention to the function of his extensor digiti quinti proprius and extensor pollicis longus, which was easily demonstrated over the dorsum of his atrophied hand. On examination the function of the extensor indicis proprius could also be demonstrated. Since these were not essential to hand function and were the only muscles that the patient could spare, it was decided to transfer them for other tasks. The extensor digiti quinti proprius was substituted for the opponens pollicis, the extensor indicis proprius for the flexor digitorum profundus of the index finger, and the extensor pollicis longus for the flexor pollicis longus. This was done by detaching the extensor digiti quinti proprius at the metacarpophalangeal joint and suturing its stump to the extensor digitorum communis tendon. The extensor indicis proprius was severed at the metacarpophalangeal joint and its tendon sutured to the extensor digitorum communis tendon. The extensor pollicis longus was divided at the metacarpophalangeal joint and the distal segment sutured to the extensor pollicis brevis. The tendons were followed back above the distal radio-ulnar joint and pronator quadratus. The interosseous membrane was divided and partially excised. Since these small muscles originate in contiguity with the interosseous membrane, they are readily displaced toward the palm and can be sutured anteriorly as desired. In this case, the extensor pollicis longus was sutured to the flexor pollicis longus. Anastomosis was performed between the extensor indicis proprius and the flexor digitorum profundus. The extensor digiti quinti proprius was led beneath the volar carpal ligament and attached to the dorsal ulnar aspect of the first metacarpophalangeal joint.

The immediate postoperative result was satisfactory, but within three months, as proved at later inspection, the extensor digiti quinti proprius and flexor pollicis longus had become adherent. The terminal phalanx of the thumb had fallen into flexion deformity because of failure of fixation to the extensor pollicis brevis. This was corrected by excision of the volar carpal ligament and careful separation of the tendon tunnels of the flexor pollicis longus and extensor digiti quinti proprius. Such a complication could have been avoided by suturing the extensor pollicis longus tendon to the flexor pollicis longus above the volar carpal ligament. The terminal joint of the thumb was then fused. At the last examination, thumb flexion and opposition were good. The extensor indicis proprius transfer was totally inadequate, and although it provided a trace of function, it was abandoned in favor of suturing the index flexor to the third finger flexor, permitting simultaneous flexion of these fingers.

This patient had no interosseus function and the strong finger extensors caused hyperextension with resultant clawing of the hand. A metacarpal bone block was attempted. Although results were excellent for the first eleven months the block then became ineffective. Since that time two additional bone blocks have been done. In one patient the joints became so stiff that they approached metacarpophalangeal arthrodesis. In the other the result was fair because of the insertion of projecting bone grafts in the metacarpal-head clefts. However, the fingers were fairly stiff and the metacarpophalangeal joints tended to drift ulnarward.

Although this procedure had promise at an early stage, prolonged follow-up has proved it inferior to other recognized techniques.

Wrist Motion and Stability

Wrist stability is essential for the adequate transference of muscle power from forearm to fingers. This stability may be provided in the form of active wrist musculature, by transfer of volar wrist musculature to the dorsal surface, or by arthrodesis. Wrist extension is essential if flexor tenodesis is planned to supply grasp. This procedure has been used with supination providing motor power, but the results are definitely inferior to those secured when there are active wrist extensors. Active wrist extension can be gained through the use of wrist flexors (flexor carpi ulnaris, flexor carpi radialis, and although we have never used it, we are certain that the brachioradialis would provide suitable wrist extension). Occasionally, wrist muscles may be in such poor balance that extension is excessive in ulnar or radial deviation. This can be corrected by transplanting the strong wrist muscle closer to the mid-line. Wrist flexion is never specifically sought; it is more often an undesirable motion which can prevent efficient use of finger flexors and demand arthrodesis of the wrist. When the wrist is flail, or when it cannot be surgically stabilized adequately by its musculature, arthrodesis should be performed.

Pronation and Supination

Pronation and supination of the arm are more important than wrist function except when flexor tenodesis is done. Most activities are done in pronation (witness the effect of the fixed pronation deformity with radio-ulnar synostosis). However, wrist function is important to the average patient. Normally the supinator alone acts through the entire range of supination, although the brachioradialis and biceps brachii are also strong accessory supinators. The pronator teres and pronator quadratus largely effect pronation, but all those muscles arising from the medial epicondyle of the humerus assist in this function. As the biceps brachii can be transferred to the side of the radial tuberosity opposite its normal insertion, so the insertion of the pronator teres can be transferred to the opposite surface of the radial shaft, thus alternating the function of these muscles. If severe contracture of the interosseous ligaments is present, it must be relieved by section or excision before a satisfactory result can be obtained by either procedure. Active supination can successfully be provided by use of the palmaris longus or the flexor carpi ulnaris redirected dorsally to the radial shaft. The tendon of the transplanted muscle is led around the ulna rather than between the radius and ulna. Since pronation contracture is not uncommon following a Steindler flexorplasty, the use of the flexor carpi ulnaris or palmaris longus to supply supination is frequently necessary. The latissimus dorsi or pectoralis major, transferred from the coracoid to the radial tuberosity, will replace the function of supination and that of elbow flexion.

Elbow Motion and Stability

Elbow motion or stability is the most essential consideration after that of grasp. Elbow flexion is best provided by Steindler's procedure in which the flexor mass arising from the medial humeral epicondyle is transferred proximally on the humeral shaft. Unless these muscles (flexor carpi radialis, flexor carpi ulnaris, palmaris longus, and pronator teres) are strong, the result cannot be satisfactory. Steindler recognized and clearly stated

this fact. Depending upon the decreasing strength of these muscles as a group, results will be proportionately poor. Under ideal circumstances, after this transfer, a patient can lift up to fifteen pounds. Full elbow extension following this procedure is not usual, nor is it desirable, for the elbow joint is more easily flexed from a position of slight flexion than from one of full extension. For this reason we have occasionally used elbow bone block with a Steindler flexorplasty, especially when working with muscles weaker than those ideally suited for transfer. The triceps brachii can be moved anteriorly to provide elbow flexion. It gives strong flexion but has limited excursion; it will provide only about one-third of the normal range. For this reason, the muscle should be placed to provide a mid-range of elbow flexion. We have used the long head and lateral head, eliminating the short head. Obviously this narrowed range will result in some flexion contracture and the transfer should be placed for mid-range usefulness.

After pectoralis major transfer, a modification of that described by Clark, the patient has up to eight pounds of flexion power at the hand. The ability to lift five pounds is the average; therefore, more should not be expected. The latissimus dorsi transplant will give results similar to that of the pectoralis major. The expected range is approximately two-thirds of complete elbow flexion, although occasionally a complete range of elbow flexion may be attained. The sternocleidomastoid transfer to the radial tuberosity as described by Bunnell is useful and will provide elbow flexion, but, in our very limited experience, the replacement strength is relatively weak. Perhaps in combination with bone block the procedure may be of greater functional value. Elbow stability in the flexed position can be obtained from bone block or arthrodesis. This allows objects to be carried in the hand or supported by the flexed forearm and may be an important consideration in supplying a stable link in improved upper-extremity function. Arthrodesis should be reserved for special circumstances.

Although it is essential for very few activities, elbow extension is worth replacing when such procedure is indicated. In most situations gravity effects this function. It has been stated that crutch-walking depends on elbow extension. Certainly elbow extension is useful, but far from essential when triceps clips and straps can be used. However, for effective overhead arm use and in many pushing activities, elbow extension is very important. It can be regained or improved by Ober's roll back operation or by the use of the latissimus dorsi as described by us. We once attempted pectoralis major transfer to provide triceps brachii replacement, but stretching of the neurovascular bundle rendered the operation unsuccessful. The biceps brachii can replace the triceps brachii. In this transfer, the brachialis is left in its normal location. We have had no experience with this procedure.

Scapulohumeral Function and Stability

No matter how efficient the hand and elbow may remain, without scapulohumeral control the functional result will be poor. Humeral rotation is essential for many activities; it allows the appropriate positioning of the hand and forearm in writing and eating. Internal rotation is effected by the pectoralis major, teres major, latissimus dorsi, and by the subscapularis. External rotation is accomplished by the supraspinatus, infraspinatus, teres minor, and to a lesser degree by the posterior head of the deltoideus and scapular head of the triceps brachii. Results of L'Episcopo's procedure and modifications of it provide external rotation when the latissimus dorsi or teres major are active in conjunction with other internal rotators. Humeral flexion allows the humerus to be placed anterior to the coronal plane so that the arms do not lie ineffective at the sides of the body. We have used Hildebrandt's procedure to improve humeral forward flexion and abduction, but suggest that in selected cases the sternocleidomastoid could well be attached to the anterior border of the humerus to supply this important function. Certainly the muscle should be more effective in this capacity than as an elbow flexor.

Humeral extension is useful in arm bracing; but as a motion to be gained by muscle

replacement it is relatively unimportant; we have made no effort to improve this function. Humeral abduction, which includes a range of forward flexion, is less important functionally than forward flexion. It is, however, a desirable goal. Shoulder arthrodesis and good scapulothoracic muscles are of the greatest importance in this replacement since adequate strength and stabilization can thus be obtained. However, since shoulder arthrodesis has many disadvantages, there should be active replacement whenever possible. One should remember that there are two important muscle actions necessary for shoulder abduction, those of the deltoideus and the muscles of the short rotator cuff, including the long head of the biceps brachii. If the short head of the biceps brachii and scapular head of the triceps brachii are active, they may be moved forward on the acromion after the technique of

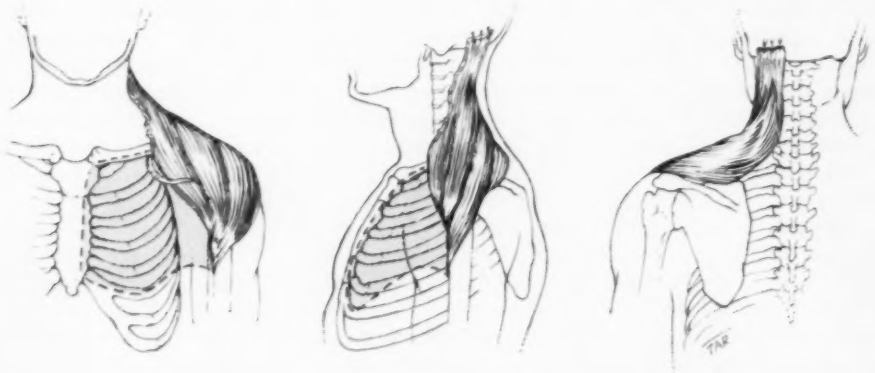

FIG. 1

Drawings show the transplantation of the entire pectoralis major to the shoulder. The muscle insertion is undisturbed; its origin is transferred cephalad. The inferior sternal fibers reach nearly to the ligamentum nuchae. The muscle should be firmly secured in the neck and along its posterior margin.

Ober. In this location they can provide some improvement in humeral abduction even without the action of the short rotator cuff, although the function will be most effective when these muscles are active. Success of Hildebrandt's procedure, first described in 1906, requires a functional short rotator cuff. This procedure was held in favor for several years, after which it fell into disuse. We presume that due to early enthusiasm injudicious application of the method caused loss of favor. The procedure is an excellent one in properly selected cases. It is best used to replace the anterior and middle segments of the deltoideus when there is a good posterior section of the deltoideus and strong enough short rotator cuff. A patient was treated successfully in whom the long head of the triceps brachii and the short head of the biceps brachii were active. The biceps and triceps brachii could efficiently stabilize the glenohumeral joint at 45 degrees of abduction. Full abduction was possible following transplantation of the pectoralis major. The following patient was also successfully treated.

F.M., aged thirty-one years, was hospitalized for poliomyelitis in September 1954 for about six months. He was referred to us by his physiatrist for surgical consideration in March 1956, following an upper-extremity progressive-resistance exercise program which had been well executed. At the time of his referral, the musculature of the left upper extremity showed good to normal function of the hand, wrist, elbow, and scapulothoracic muscles. Examination of the scapulohumeral musculature revealed fair minus external rotators. The deltoideus was poor minus posteriorly, poor centrally, and inactive anteriorly. Function of the latissimus dorsi and pectoralis major muscles was good. The right upper extremity was also involved by paralysis, but was functionally more efficient.

On April 25, 1956, the entire left pectoralis major was moved from the chest wall to the left side of the neck to replace the functions of the anterior and central portions of the deltoideus (Fig. 1). Postoperatively a cast was used for four days, following which the arm was maintained in an airplane splint. On June 4, 1956,

the patient could abduct the bent arm completely, but there was some residual scapulohumeral contracture. He began a program of active abduction from the splint and from his side to as near full abduction as possible, both while standing and while supine. The brace was discontinued within two weeks following this examination. On November 17, 1956, seven months after operation, the patient could move the extended arm, holding a two-pound weight, through a complete range of abduction. There was no scapulohumeral contracture at this examination. The patient commented that his major gain had been in shoulder stability and arm placement. The transplanted muscle tired easily at that early date, but we expect that it will increase in endurance over the next several years.

Hildebrandt's procedure, as originally described, used only the upper two-thirds of the muscle. We have preferred to modify the technique. The origin of the pectoralis major is exposed through a curved incision from the axilla around the lateral margin of the muscle to the mammary line anteriorly. Through this incision the entire muscle is elevated and its origin detached. It is then transposed to lie upside down so that the lower costosternal edge lies almost in a superior line across the scapula and as near the superior and medial line and cervical spinous processes as is possible. It is secured along the line of the scapula and sutured over the central portion of the acromion. The inferior axillary edge is carried as near to the deltoid mid-line as possible. The insertion is left undisturbed. Postoperatively, the humerus is secured in the abducted and forward flexed position by a spica or brace. Three weeks postoperatively, active function may be started from the spica or brace, and at six weeks the brace may be removed for short periods.

We have had only slight experience with Mayer's use of the trapezius and cannot comment on this procedure except to note that those done in our clinic have functioned chiefly as tenodeses. We have not used the transfer of the origin of the posterior third of the deltoideus forward on the acromion. When the rotator cuff is active, the procedure would seem to be sound functionally, but otherwise should be of little help. In our opinion, shoulder arthrodesis for properly selected patients is an excellent procedure. If arthrodesis is to be effective, the scapulothoracic muscles must be strong enough to rotate the upper extremity. For many patients with severe involvement who need shoulder mobility for self-care and daily-habit activities, it is contra-indicated. It can be brilliantly successful, however, in bridging the gap in the kinetic chain which has resulted from isolated scapulohumeral paralysis. A shoulder fused at a 60-degree angle can often be satisfactorily used by the patient. However, in general we feel that a shoulder in 30 degrees of forward flexion and from 45 to 50 degrees of abduction will give the benefits of a stable scapulohumeral joint and can be placed through the most essential portions of the arc of motion without the usual drawbacks of the more extreme position. From this position the elbow will fall against the body and there is little likelihood of an unsatisfactory cosmetic appearance of the scapulohumeral region. The range of scapulothoracic motion can be improved by excision of the distal portion of the clavicle. When shoulder arthrodesis is done on children from eight to fourteen years of age, the accessory motion that develops provides a surprising range of adduction and some apparent rotatory motion, since movement is on the arc of the chest wall. In our practice we have not found removal of the distal portion of the clavicle necessary in this younger age group.

Scapulothoracic Function and Stability

This function should be separated into three muscular factors representing three major force-couple factors: the upper trapezius and levator scapulae component, the mid-trapezius, rhomboidei and lower trapezius component, and the serratus anterior component. Effective movement at the scapulothoracic region is necessary for proper arm placement.

The function of the upper trapezius and levator scapulae can be supplemented by moving the levator scapulae laterally, thus increasing its effectiveness as a rotator, or the origin of the sternocleidomastoid can be transplanted from the clavicle to the outer edge of the acromion.

The mid-trapezius and rhomboidei component provides a stable position for rotation of the scapula. If it does not function, the scapula is pulled forward by the serratus anterior component which then has no force against which to work. Replacement of this function has been handled in various ways. The scapula may be moved medially after lifting the rhomboidei and the trapezius; the scapula may be suspended from the cervical and thoracic spinal extensor musculature, the scapula may be suspended from the vertebral spinous processes, or it may be stabilized by fascia lata between the two scapulae. The strap of fascia should lie just below the scapular spines and close to the center of scapular rotation so that motion will not be impeded. Function of the serratus anterior component may be successfully replaced by transplanting the pectoralis major, pectoralis minor, teres major, or latissimus dorsi. We have had experience only with the transfer of the pectoralis major from its insertion to the vertebral scapular border; this is done with ease

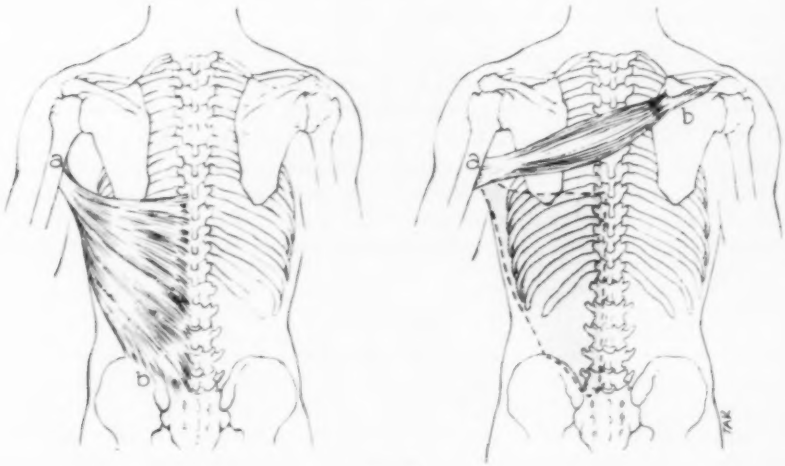

FIG. 2

Drawings showing the transplantation of the left latissimus dorsi to the right scapula. Left: The insertion (*a*) of the muscle on the left humerus remains undisturbed. Right: The tubed origin (*b*) of the muscle is attached to the right scapula.

and is successful functionally. Acting upon a stable medial border capable of rotation, scapular rotation normally occurs when the upper portion of the trapezius lifts the acromion, and the serratus anterior pulls the inferior angle forward. This function depends upon the contraction or stability of the rhomboidei or trapezius. Fixation of the scapula to the chest wall has been suggested; although we have had no experience with this procedure undoubtedly under unusual circumstances it may provide a stable scapular position upon which the scapulohumeral muscles may act.

We have outlined several approaches to the problem of improving scapulothoracic rotation. However, there are undoubtedly other excellent possibilities. One of our previously reported cases demonstrates the result of an unusual transplant combination.

This boy, E. T., had poliomyelitis at the age of five years and was not operated on by us until he was thirteen and one-half years old. When first admitted to Shriners' Hospital in San Francisco in November 1952, except for a trace to poor minus function of the trapezius, he had a flail right shoulder and elbow. On March 9, 1953, the origin of the right sternocleidomastoid was transferred to the right acromion to reinforce trapezius power. On May 11, 1953, a strip of fascia lata was placed on the lower margin of the scapula and attached anteriorly to the second rib above the level of the scapular attachment. Replacement of upper trapezius force and prepositioning of the vertebral border of the scapula forward permitted shoulder elevation and weak forward rotation of the scapula. Motion pictures of the patient, made April 22, 1953, showing

the function of the sternocleidomastoid transplant, corroborated its effectiveness. Shoulder arthrodesis was done November 9, 1953. On March 30, 1953, a bone block had been done on the right elbow, and on June 22, 1953, an effort was made to provide active elbow flexion through the use of the left latissimus dorsi (Fig. 2). This muscle was freed from its origins at the lower vertebral spinous processes, left iliac crest, and lumbodorsal fascia. After appropriate mobilization of the muscle to its insertion on the humerus, the muscle was placed in a tunnel across the mid-line to lie over the superior surface of the right scapula and over the right humerus anteriorly. A four-inch gap between the latissimus dorsi origin and radial tuberosity was bridged with homogenous fascia. Postoperative infection resulted from a too generous use of foreign material and subsided only after all silk was removed from the wound.

At examination in June 1956, we were impressed with the strength of scapular rotation in this patient and noted that the sternocleidomastoid transplant merely assisted at the onset of movement or when a heavy load was placed upon the arm. The most active scapular rotator was the latissimus dorsi transplant, now adherent to the superior border of the scapula just lateral to the insertion of the levator scapulae. The transfer of the latissimus dorsi had not impaired the use of the strong left upper extremity in any way. Thus, the left latissimus dorsi had become an active rotator of the right scapula. Admittedly, this is not a usual circumstance. It does, however, demonstrate the success with which two muscles not usually transferred to the scapula may provide synchronous scapular rotation.

Trunk stability may need reinforcement to permit proper arm placement. When lateral trunk stability is lacking, one arm cannot be raised without overbalancing the body so that it falls toward the outstretched arm. A corset or other external support may be used, but fascial abdominal transfer after the manner of Lowman is most appropriate. When the muscles of the abdomen are paralyzed and the trunk is unstable laterally the transfer is best accomplished by the use of anterior crisscross straps and lateral bands placed from a fixed rib to the iliac crest. When an abdominal muscle is active, appropriate bands are placed from it to the ribs or iliac crest to ensure trunk stability and thus improve arm function.

CONCLUSION

While this paper makes no attempt to outline all known techniques, it is offered in the hope that it may prove useful as a guide in the proper evaluation of the paralyzed upper extremity and be of aid in helping to secure optimum function by substitution. It not only points out the fundamental kinetic problems, but suggests an intelligent approach to many of them. It is our hope that this paper may stimulate independent thinking and ingenuity to help in the solution of the difficult paralytic problem.

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DISCUSSION

Dr. C. Edwin Irwin, Atlanta, Georgia: Proper function of a muscle transferred into the deep muscles requires a strong wrist extensor; tenodesis also plays an important part. Finger extension is much easier to restore than finger flexion. If the patient has active intrinsic musculature, any transfer into the common extensors need only stabilize the metacarpophalangeal joints. The intrinsic muscles will extend the fingers. As for flexorplasty at the elbow, I have been using Eyler's modification of the Steindler flexorplasty. No

portion of the flexor carpi ulnaris is used, but rather the flexor digitorum sublimis, palmaris longus, pronator teres, and flexor carpi radialis. After this muscle mass is detached with the nerve supply intact, it is prolonged with a free graft and fastened about one and one-half inches above the elbow on the anterolateral aspect of the humerus. As a result of this procedure, some of the pronation is overcome.

DR. LEO MAYER, NEW YORK, N. Y.: This is a most interesting paper and I feel that we have been given some new ideas. These are:

1. Utilization of the extensor tendons of the fingers as flexors by bringing them through the interosseous membrane proximal to the pronator quadratus.

2 Transfer of the latissimus dorsi from one side of the body to the opposite side. It is attached to the scapula in such a way as to rotate the scapula. Dr. Schottstaedt has described a method of doing this and of conserving the motor supply of the muscle.

3. Use of a bone block to prevent hyperextension at the metacarpophalangeal joint. This operation is indicated in those patients in whom the Bunnell transplantation of the flexor digitorum sublimis tendons cannot be carried out.

In addition to these three new ideas, I was much interested in the reference to the Hildebrandt operation. The report of this procedure was published before I began my research on tendons in 1912. My chief, Professor Biesalski, and I performed it on three patients but the results were disappointing. It was only in later years that I understood why. Better understanding of the kinesiology of the muscles of the shoulder occurred as a result of the research of Abbott and his associates. They proved that the act of abduction requires a muscle group. In other words, action of the deltoideus alone will not produce abduction. There must be an additional muscle acting with it, usually the infraspinatus or the teres minor. The success of the Hildebrandt operation and also of the trapezius operation which I have devised depends upon the action of this muscle group. This was well demonstrated last year at the Academy meeting in the film showing the complete restitution of shoulder abduction following loss of function of the deltoideus in a gunshot accident. In that case the trapezius which was transplanted had the effective aid of the infraspinatus.

Finally, one word about Steindler's elbow operation. I wish again to stress the importance of this operation. I think it is the most important contribution that Steindler has made for the benefit of poliomyelitic patients. It can be used in a great variety of cases and if one uses careful dissection and techniques good results are possible. One should not allow a severe flexion contracture at the elbow to develop. This flexion contracture can be prevented by using a turnbuckle splint which stretches the transplanted muscles. Extension to an angle of 160 degrees should be secured in every case.

Osteochondritis of the Greater Trochanteric Epiphysis

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Osteochondritis of the greater trochanteric epiphysis is apparently a relatively rare affection of this structure occurring during adolescence and is related in its etiology and pathology to an identical process occurring in other epiphyses. The original description of this entity has been credited to Felix Monde but correspondence with the editor of the journal in which it was published indicates that the true credit belongs to Felix Mandl. I have been unable to find other reports on the disease at this site beyond an occasional

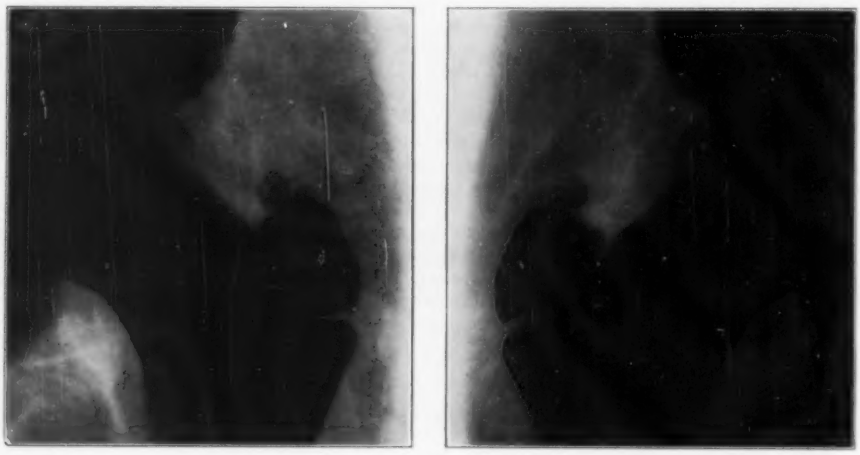

FIG. 1

July 11, 1956. Roentgenograms reveal fragmentation of the superior pole, mimimal widening of the epiphyseal line, and increased density on both sides of the cartilaginous plate.

reference to its existence. Numerous textbooks report the existence of osteochondritis in the greater trochanteric epiphysis and refer to the condition as Monde's disease. The relative rarity of the condition is evidenced by the absence of roentgenograms reproduced to illustrate the condition in existing textbooks of orthopaedics and roentgenology [1,2].

In the article falsely ascribed to Monde, Mandl described a widening of the epiphyseal line of the olecranon process occurring in osteochondritis of the epiphysis of the ulna. He also described a similar condition which occasionally occurred in the trochanteric epiphysis of the femur. There was no mention of fragmentation. Mandl offered no case history and no illustrations of the condition in the trochanteric epiphysis.

CASE REPORT

Approximately six months before the author examined the patient, an abnormality of gait described by his mother as waddling and shuffling developed. There were no other symptoms present at that time. The patient was seen by the family paediatrician who believed that the defective gait was the result of pes planovalgus which was present and prescribed basic orthopaedic oxfords. Approximately three months later, pain developed in both hips during athletics and with sustained walking or play. His abnormal gait continued and his mother noted the development of lassitude and marked increase in fatigability. The patient was obese and was referred to a laboratory for routine examination of the blood, for urinalysis, and for a basal metab-

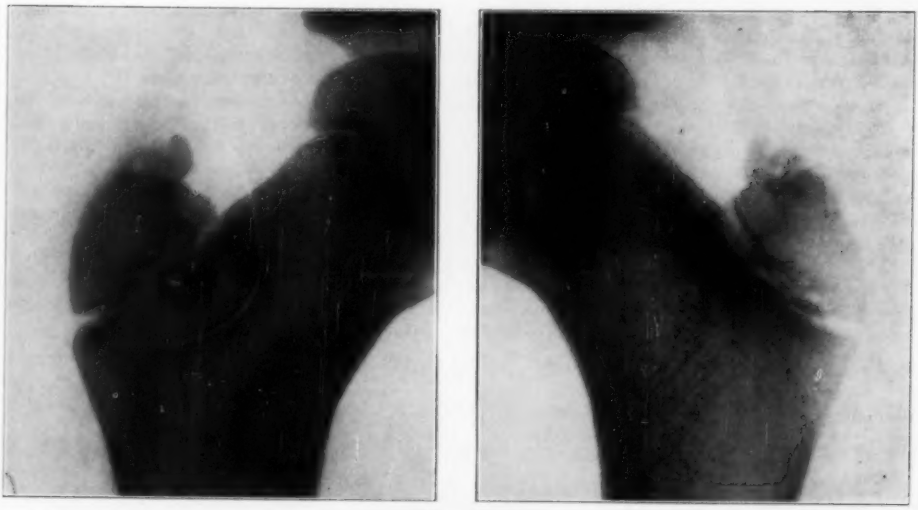

FIG. 2

August 31, 1956. Roentgenograms show increased widening of the epiphyseal line and increased ossification at the site of fragmentation.

FIG. 3

February 17, 1957. Roentgenogram shows persistent widening of the epiphyseal line but almost complete ossification at the site of fragmentation.

olism test. The results of these were all within normal limits with the exception of the basal metabolic rate which was −11 per cent. He was placed on a weight-reduction diet and given one-half grain of thyroglobulin per day. The patient continued to walk in a shuffling and waddling manner and continued to complain of generalized pain about the hip and groin with increased activity. The discomfort was aggravated by climbing stairs. He was referred to another orthopaedic surgeon who considered the possibility of progressive muscular dystrophy. The patient was then referred to me for confirmation of the diagnosis.

The patient was seen on July 14, 1956. Roentgenograms had been made three days prior to this. At the time of the first examination the patient, a ten-year-old obese white male, was of the Frölich type. His height was sixty-one inches and his weight was 130 pounds. The laboratory data were available and were considered non-contributory to the diagnosis of his hip discomfort. The patient walked with a gait seen in patients with paralysis of the glutaeus medius. With each step there was an accentuated shift of the trunk from side to side. The patient had Grade I pes planovalgus, but had no symptoms in the feet or calves. Examination of the lower extremities revealed equal limb length and no atrophy on comparative measurements of the thighs, knees, or calves. There appeared to be a normal range of hip motion. The patient complained of discomfort with the ankle-to-opposite-knee test and with compression over the trochanters.

Roentgenograms made of both hips revealed widening of the epiphyseal line of the greater trochanters, most apparent at the medial and lateral borders. There was a marked increase in the trabecular density on the metaphyseal side of the epiphysis and some increase on the epiphyseal side of the epiphyseal plate. There was bilateral fragmentation of the superior poles of the epiphyses of the greater trochanters.

In contrast to osteochondritis in an articular epiphysis subjected to compression forces, osteochondritis of the trochanteric epiphysis is a self-limiting disease. Therefore, no specific therapy was recommended beyond restraint of activity, especially athletics and gymnastics. The patient was seen again on August 31, 1956, approximately six weeks after his initial visit. He had no complaints of discomfort in the hips, but he continued to walk with a glutaeus-medius gait. Roentgenograms made at that time revealed an increased width of the epiphyseal lines, especially at the medial and lateral borders. There was also some increased ossification in the area of the fragmentation at the superior poles of the greater trochanters. On February 17, 1957, the patient was seen again. At that time, he walked with a normal gait and, with his restricted activity, he had no discomfort. Roentgenograms revealed that, although there was persistent widening of the epiphyseal lines, the ossification at the superior poles of the trochanters was almost complete and that the fragmentation had almost disappeared. The patient was advised to resume normal activity.

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DISCUSSION

Analysis of Methods of Fusion for Scoliosis

(*Continued from page 554*)

Autogenous bone is not difficult to get. Schmidt has pointed out that with an extension of the mid-line incision to the sacrum access to either ilium is possible where grafts may be quickly obtained and later cut into matchlike sticks by an assistant. This bone should be added after obliteration of the articular facets and preparation of the posterior surface of the spine. Dr. Moe's use of block grafts in the articular facets may be still better.

Research is still necessary in the prevention of pseudarthrosis. There must be an individual factor, not mentioned by Dr. Moe, inherent in the patient. Why is it that sometimes a solid mature fusion develops promptly, while in another patient, under almost identical conditions, even autogenous bone seems to melt away? Perhaps the metabolic factor is more important than some of us realize.

Some of you must help to study the problem, search for the factors producing pseudarthrosis, and eliminate them almost entirely. Until this is done the results of treatment of scoliosis cannot be considered satisfactory.

Dr. Joseph C. Risser, Pasadena, California: The treatment of over 250 patients with scoliosis by correction and spine fusion in a ten-year period is hard work. Great credit is due Dr. Moe for a very careful review of his treatment of scoliosis, and his continued search for improvements in technique to achieve a solid fusion. He has found that addition of bone-bank bone is of less value to the fusion than is autogenous bone. He has realized the hard way that articular-facet fusion is the basis of a good spine fusion. It is impossible to talk about the technique of spine fusion and articular-facet fusion without mentioning Hibbs and his pioneer work begun forty-five years ago. Knowledge of his work would undoubtedly have prevented many pseudarthroses, not only in Dr. Moe's patients, but in those of many others.

(*Continued on page 697*)

Ossification of the Distal Femoral Epiphysis

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Variations in the pattern of ossification of epiphyses in the growing skeleton have often been erroneously interpreted as evidence of disease. Longitudinal roentgenographic studies of normal children demonstrating wide variations in the pattern of ossification have led to a more thorough appreciation of the range of normal variation. However, current knowledge is far from adequate and many more longitudinal studies of healthy children are needed.

The authors have been impressed by the frequency of marginal irregular ossification of the distal femoral epiphyses in healthy children. Our inability to determine the signifi-

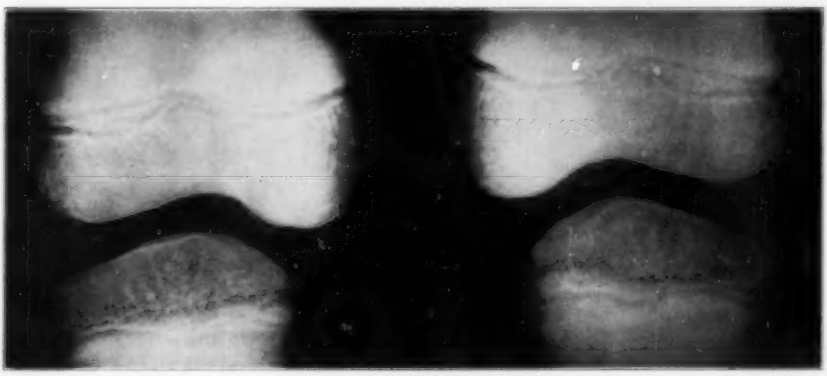

FIG. 1-A

FIG. 1-B

Figs. 1-A and 1-B: Roentgenograms showing an example of Group I irregularities. Although the changes are best seen in the tunnel projection (Fig. 1-B), they are also visible in the anteroposterior view (Fig. 1-A).

FIG. 2-A

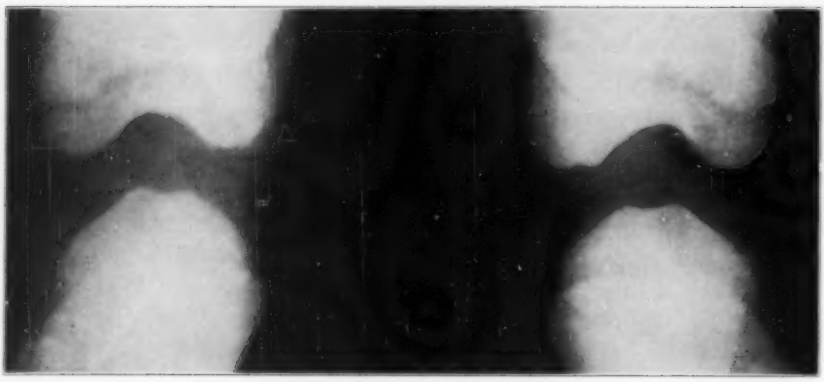

FIG. 2-B

FIG. 2-C

Figs. 2-A and 2-B: Roentgenograms showing Group I irregularity in which there is adjacent separate focus of calcification in the epiphyseal cartilage of the right knee (arrow in Fig. 2-B).

Fig. 2-C: Line tracing of roentgenogram of right knee shows separate focus of calcification.

cance of this finding prompted us to attempt to learn more about the appearance of the normal knee in the growing skeleton.

Accordingly we obtained roentgenograms of the knees of 147 children between the ages of three and thirteen years. These children were all free of any symptoms or signs at the knees and were referred to the x-ray department for examination of the skull, chest, abdomen, or gastro-intestinal tract. Roentgenograms were obtained in anteroposterior, lateral, and tunnel (Holmblad) projections[6].

RESULTS

Marginal irregularities in the distal femoral ossification center were common. For purposes of evaluation, these were divided into three groups.

In Group I were varying degrees of roughening of the margins. Occasionally, there were separate small foci of calcification just beyond the roughened edge of the main center (Figs. 1-A through 2-C).

FIG. 3-A

FIG. 3-B

Figs. 3-A and 3-B: Roentgenograms show the deep indentations in the lateral condyles characteristic of these Group II irregularities.

In Group II were larger localized marginal irregularities in the form of indentations (Figs. 3-A and 3-B).

In Group III were irregularities of the same kind as those in Group II except that there was an independent island of bone in the marginal crater (Figs. 4-A, 4-B, and 4-C).

The findings are summarized in Table I. The outstanding feature was that the margins of the ossification centers were more commonly irregular than smooth. Irregularity was present in 66 per cent of the boys and in 41 per cent of the girls. Of the affected condyles, both were involved in 44 per cent of the children, only the lateral condyle in 44 per cent, and only the medial condyle in 12 per cent. The changes were often bilateral but not always symmetrical.

DISCUSSION

Irregularities such as those in Group I have previously been described by Sontag and Pyle. In a longitudinal study of 220 children from the age of one month to seventy-two months some irregularity of outline or texture of the distal femoral epiphysis was an almost universal transitory finding. Their explanation of the production of the irregular roentgenographic appearance was that in a rapidly growing epiphysis the zones of prolifer-

FIG. 4-A

FIG. 4-B

Figs. 4-A, 4-B, and 4-C: The defect in the left knee in this Group III type of irregularity is similar to those of Group II, except that there is an independent calcific or bone island in the marginal crater.
Fig. 4-A: Tunnel view. Fig. 4-B: Anteroposterior view. Fig. 4-C: Lateral of left knee.

ating cartilage and provisional calcification are considerably deeper than in a slowly growing epiphysis. When growth is extremely rapid, as it is at the distal end of the femur, the orderly processes of cartilage proliferation and provisional calcification can be disturbed. There is thus available, they noted, a wide zone in which irregular or spotty mineralization can, and apparently does, occur. Foci of provisional calcification can appear entirely beyond the image of the main mass of calcified cartilage during periods of active growth. As the invading osteoblasts replace the provisionally calcified cartilage by bone trabeculae, a regular outline is again established.

This explanation seems reasonable. It is quite conceivable to us that a transition from smooth to irregular outline may be repeated during periods of accelerated growth. It is also easy to conceive how the irregularities could be erroneously interpreted as evidence of destruction. Similar irregularities are found in other epiphyses but the changes are most distinct at the distal end of the femur, where growth is extremely rapid, especially during early childhood.

Of particular interest to us, however, is the type of irregular mineralization found in Groups II and III. Roentgenographically the changes in these knees appear to be identical to the changes observed in osteochondritis dissecans. Unfortunately, it was possible to obtain follow-up studies on only two of our patients. In one, roentgenograms made eighteen

FIG. 4-C

months after the original examination showed partial filling of the radiolucent defects in the femoral condyles. In the other, there was a calcific density within a radiolucent defect in the medial femoral condyle which was smaller fifteen months later. The entire defect had filled in, the separate calcification had fused with the remainder of the epiphysis, and the condyle had a normal appearance twenty-seven months after the original roentgenograms.

The changes in the second patient may have represented an instance of osteochondritis dissecans with spontaneous healing. This patient was referred to the x-ray department because of mild discomfort in one knee for three weeks following mild trauma. Physical findings were normal, and symptoms disappeared permanently soon thereafter. Treatment consisted in the use of crutches for three months. This patient and one other were included in the study, despite the fact that they were referred to us primarily for roentgenographic examination of the knees, because their symptoms were attributable to mild recent trauma and disappeared permanently within a few days.

There were three other instances of spontaneous disappearance of the Group III defects. However, these are excluded from the study because of the presence of intermittent and recurrent symptoms in the knees for which the roentgenographic studies were performed. It is of interest that in all three the changes were bilateral although symptoms were present in one knee only (Figs. 5-A, 5-B, and 5-C).

Examples of children with roentgenographic diagnosis of osteochondritis dissecans have appeared in the literature with recommendations for various methods of therapy, ranging from surgery through immobilization in plaster and avoidance of weight-bearing to judicious neglect[3, 4, 5, 8, 9, 11, 12, 13]. Green reported a series of twenty-four patients with roentgenographic diagnosis of osteochondritis dissecans in the knees of whom three under-

TABLE I

INCIDENCE OF DISTAL EPIPHYSEAL IRREGULARITIES IN THE FEMORA OF 147 CHILDREN

Age (*Years*) and Sex	No Irregularity	Group I	Group II	Group III
3				
Boys		2		
Girls		3		1
4				
Boys	1	4		1
Girls	1	5	1	1
5				
Boys		6	1	2
Girls	5	4	2	2
6				
Boys	2	3	3	1
Girls	4	3	1	1
7				
Boys	2	4	2	2
Girls	3		1	1
8				
Boys	1	4	3	3
Girls	4			
9				
Boys	3	6		1
Girls	7			
10				
Boys	5	1	2	
Girls	4			
11				
Boys	7			2
Girls	4			
12				
Boys	4		1	1
Girls	5			
13				
Boys	3			
Girls	1			
Total	66	45	17	19

went surgical exploration at some time during the course of immobilization therapy. The gross appearance of the cartilage was normal in all three, and the author states that the site of the roentgenographic defect could be located only by placing heavy pressure on the cartilage and observing the resilience arising from the subchondral defect. He recommended plaster or brace immobilization. Green's series cannot be compared directly with ours because of differences in age distribution. In his group there were twenty-seven patients

Figs. 5-A, 5-B, and 5-C: Roentgenograms of a thirteen-year-old boy who had intermittent pain in the right knee and occasional giving-way of the right knee for two months. The physical examination was negative.

Fig. 5-A: There is slight irregularity in the margin of the right medial femoral condyle. On the left the appearance is that of osteochondritis dissecans.

Fig. 5-B: Despite occasional recurrence of symptoms, the patient was allowed unrestricted activity without treatment. This roentgenogram made two and one-half years later shows complete disappearance of the changes on the left.

Fig. 5-C: There is almost complete ossification of the defect on the right.

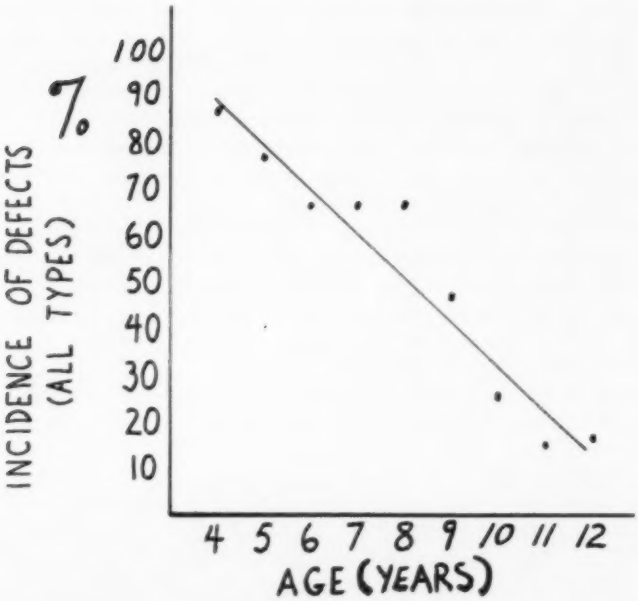

CHART I

FIG. 5-A

FIG. 5-B

FIG. 5-C

including three with osteochondritis dissecans of the elbow or ankle. Ten of the twenty-seven were twelve years of age or older and eleven were between nine and twelve years. In our series there were only six patients with Group II or III changes ten years of age or older. Edelstein, on the other hand, described the cases of six patients under the age of fourteen in which the changes disappeared without any treatment.

Group II and III defects were present in 30 per cent of all male and in 17 per cent of all female children in this study, and, with the two exceptions noted, represented a chance finding, usually bilateral, in children without any symptoms whatever referable to the knees. If osteochondritis dissecans occurred with only half this frequency, there would be residual deformities in a substantial number of children. Deformities from this cause have not been observed by us, however, despite our location in a large paediatric hospital with a substantial proportion of orthopaedic patients. The literature reflects this fact in the almost universal opinion that osteochondritis dissecans has a good prognosis in children, regardless of the method of treatment.

We suggest that uneven marginal ossification in the femoral condyles is a feature of healthy endochondral-bone formation. This hypothesis is strengthened by the fact that the incidence of marginal irregularities falls progressively with age (Chart I). It is probable that provisional calcification can be retarded in a localized segment of the epiphysis, producing a radiolucent defect. Within the area of the defect a focus of calcification can occur, removed from the main calcified mass. As both the focus of calcification and the main cartilaginous mass enlarge, the appearance of osteochondritis dissecans can be simulated.

The discovery of a normal variant in a child with some morbid condition can lead to a rationalization of a causal relationship between the two. In at least one reported case [1], an eleven-year-old girl was found to have a defect of the Group III type in one femoral condyle four years after an eosinophilic granuloma of the skull had been discovered. The author wondered whether the two conditions could be causally related. A realization of the frequency with which this type of irregularity of the femoral condyles is found is all that is necessary to discourage this form of speculation.

A final evaluation of this problem must await a longitudinal study of healthy children of both sexes between the ages of two and twelve years. The available evidence, however, strongly suggests that this is a normal variant.

SUMMARY AND CONCLUSIONS

1. Irregularities of the margin of the ossification center in the distal femoral epiphyses are extremely common in normal children.

2. Often the irregularities take a form roentgenographically indistinguishable from osteochondritis dissecans. Our data do not deny the existence of osteochondritis dissecans in the femora of children, but they do indicate that it is much less frequent than the marginal irregularities described.

3. The patients in this series were asymptomatic and, even in several omitted from the study because of mild symptoms, the changes disappeared without treatment.

4. The evidence strongly suggests that the roentgenographic appearance of osteochondritis dissecans can be simulated by a normal variant of ossification in children.

5. Since many of the irregularities are located on the posterior aspect of the femoral condyles, the irregularity will often be seen in the tunnel view, while the anteroposterior roentgenogram does not show it as clearly.

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(Continued on page 714)

Age of Fitting Upper-Extremity Prostheses in Children

A Clinical Study

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Twelve juvenile amputees, varying in age from five months to four years, comprised this clinical experiment to determine at what age a child may be satisfactorily fitted with an upper-extremity prosthesis. There were nine congenital and three traumatic amputees, representing a total of fourteen involved extremities. The study includes the factors involved in prosthetic acceptance, tolerance, development of two-arm functional patterns, and the optimum age for conversion from a temporary prosthesis to one that includes an actively controlled terminal device.

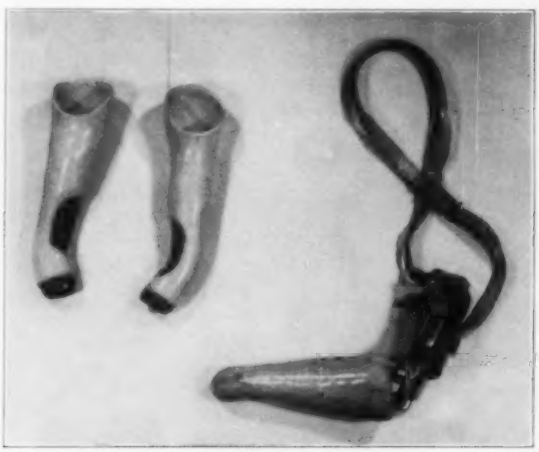

FIG. 1

FIG. 2

Photographs showing examples of the temporary prostheses used in this study. Those at the extreme left show rubber-lined volar concavities. The middle one shows elbow hinges with a half-cuff and a figure-of-eight harness. The prosthesis at the right demonstrates the terminal split for passive prehension.

The age of fitting of upper-extremity prostheses in children has long been a controversial subject. The recent upsurge of interest in the problem of the juvenile amputee has made the age of fitting a topic of even greater interest. The organization of a juvenile amputee training program by the Michigan Crippled Children Commission ten years ago has afforded the author an excellent opportunity to review a particular phase of this problem.

In 1953, Aitken and Frantz published a report on juvenile upper-extremity amputees. They suggested that juvenile amputees should be fitted with prostheses about one year prior to entering school. This was considered a satisfactory basic criterion for fitting since there was no previously established precedent for the age of fitting of upper-extremity prostheses in children. Gesell and his co-workers have made an exhaustive study of the motor development and accomplishments of children from infancy to adolescence. Careful review of this work indicated that children between the ages of four and five (approximately one year prior to admission to school) had established upper-extremity

motor patterns that would permit them not only to develop control of upper-extremity prostheses, but also would permit them to utilize the prosthesis in a purposeful, functional manner. It was in this moderately empirical manner that the decision to fit children one year before admission to school was made. Subsequent clinical experience with children fitted on the basis of this decision demonstrated that good functional results could be obtained at this stage of chronological and motor development.

Statistics indicate that between the ages of birth and seven years, the juvenile upper-extremity amputee is primarily a congenital amputee or has a congenital appendicular abnormality that is best treated as though it were an amputation. Beyond the age of

FIG. 3

FIG. 4

Fig. 3: This child is wearing a below-the-elbow prosthesis with a plastic mitten-shaped terminal device. Notice the strap across the chest which promotes better stabilization of the figure-of-eight harness in the young patient.

Fig. 4: This was the initial fitting of a patient with bilateral shoulder disarticulation. Only the right side was fitted with a prosthesis for function. The shoulder cap on the left was for balance and some cosmetic restoration. Later a functional prosthesis was added on the left. The young amputee must not be overwhelmed with hardware.

seven years, the juvenile upper-extremity amputee is primarily a traumatic or surgical amputation problem. It is believed this change in amputee type is due to the child's increasing range of activity and his increasing exposure to those mechanical aspects of our civilization which produce injuries resulting in amputation or in the necessity to use amputation as a form of treatment.

In children with congenital amputation, the short below-the-elbow amputation is the most common of all upper-extremity types. Birch-Jensen reported that 77 per cent of these children have a forearm stump less than ten centimeters long. One sees occasional

elbow disarticulations, wrist disarticulations, and partial hand amputations. True amelia is seen infrequently. The congenital above-the-elbow amputation probably exists, but no cases have been observed in this clinic to date. The non-amputation congenital appendicular abnormalities that may be treated as though they were amputations are a bizarre group of deformities, difficult to classify including phocomelia and symbrachydactylia. There is an occasional traumatic amputation, but this type is in the minority.

Congenital upper-extremity amputees have no remembered functional patterns involving both hands as do the children with traumatic amputations. From birth the

FIG. 5

FIG. 6

Fig. 5: This patient is wearing a standard below-the-elbow prosthesis on the left. She demonstrates ability to open fully the polished aluminum two-fingered hook.

Fig. 6: Here the plastisol-dipped two-fingered hook is demonstrated. Its bluntness is its major advantage for a young amputee.

congenital amputee develops a functional pattern that utilizes his deficient extremity or extremities to the maximum. This requires substitution patterns of varying types. In the unilateral amputees, everything that requires a two-handed grasp is brought toward the body to the shorter or deficient extremity. In the bilateral amputees, excessive torso, neck, and head motions are utilized to compensate for the inadequacies of the short or absent extremities. Such substitution produces postural defects, reduces efficiency, and prevents normal motor maturation.

It is assumed that the infant with an amputation uses his stump as a kind of sense organ, just as the normal child uses his hand as a sense organ. It is conceivable that as this function becomes developed with use, dependence upon it will deter acceptance of an artificial limb.

There are several good reasons for early fitting of upper-extremity prostheses in children:

1. To promote the development of a functional pattern involving both hands in the congenital amputee.
2. To mask the sense-organ function of the stump or deficient limb.
3. To prevent abnormalities and asymmetries of posture that are secondary to the

TABLE I
JUVENILE AMPUTEE DEVELOPMENT

Patient	Amputee Type	First Fitted (*Months*)	Type of Terminal Device	Prosthetic Acceptance (*Months*)	Prosthetic Tolerance (*Months*)	Gross Pattern (*Months*)
P. McF.	Left very short below-the-elbow, congenital	5	Temporary	5	5	5–16
		16	Dorrance 10X	16	16	Not indicated
R. W. Triple amputee	Bilateral, short below-the-elbow, congenital	11	Temporary, bilateral	11	11	11–13
B. M.	Left short below-the-elbow, congenital	13	Temporary	13	13	13–30
		30	Dorrance 10X	30	30	Not indicated
P. C.	Left very short below-the-elbow, congenital	16	Temporary	16	16½	16–?
		23	Dorrance 10X	23	23	Not indicated
C. B.	Left short below-the-elbow, congenital	16½	Temporary	17	17	16½–23
		21½	Dorrance 10X	21½	21½	Not indicated
G. W. Triple Amputee	Right above-the-elbow, traumatic	21				
		38	Dorrance 10X	47	38	Not evidenced
L. T.	Right below-the-elbow, congenital	26	Temporary	26	26	26–?
		27	Dorrance 10X	27	27	Not indicated
L. W. Quadruple amputee	Right above-the-elbow, congenital	28	Temporary	28	28	28–28½
		28½	Dorrance 10X	28½	28½	Not indicated
	Left above-the-elbow, congenital	33	Dorrance 10X	33	33	Not indicated
K. Q.	Right very short above-the-elbow, traumatic	33	Dorrance 10X	35	34	Not indicated
A. H.	Right short below-the-elbow, congenital	33	Temporary	33	33	33–33¼
		33	Dorrance 10X	33	33	Not indicated
A. M. Bilateral shoulder disarticulation	Right shoulder disarticulation, congenital (Shoulder cap on left)	34	Dorrance 10X	34½	35½	34–34½
G. B.	Right above-the-elbow, traumatic	47	Dorrance 10X	47	Limited	Not indicated

substitution patterns of the young upper-extremity amputee.

4. To develop prosthetic tolerance and acceptance as early in life as possible.

On the basis of these theoretical criteria, an experimental study was initiated to determine how early an upper-extremity amputee could be fitted satisfactorily with a prosthesis, and what type of prosthesis, harness, and terminal device would be most satisfactory for each age level.

The total number of amputees seen at Mary Free Bed Children's Hospital and

TABLE I
JUVENILE AMPUTEE DEVELOPMENT

Two-Arm Functional Pattern (*Months*)	Prehension Control		Awareness of Potentialities		Formal Training Time	Age at Discharge (*Months*)
	Partial (*Months*)	Total (*Months*)	Partial (*Months*)	Total (*Months*)		
5	Not indicated	Not indicated	Not evidenced	Not evidenced	2½ hrs. in 2 wks.	
Not evidenced	17	Not evidenced	17	Not evidenced	27 hrs. in 4 wks.	17
Not evidenced	Not indicated	Not indicated	12½	Not evidenced	24 hrs. in 8 wks.	13
14	Not indicated	Not indicated	14	14½	6½ hrs. in 4 wks.	30
31	30	31	31	Not evidenced	10½ hrs. in 2 wks.	31
17	Not indicated	Not indicated	16	17	6½ hrs. in 2 wks.	17
23	24½	Not evidenced	Not evidenced	Not evidenced	21 hrs. in 6 wks.	26
17	Not indicated	Not indicated	16½	17	12 hrs. in 2 wks.	21½
21½	23	Not evidenced	23	Not evidenced	31½ hrs. in 6 wks.	23
Not evidenced	44	47	47	Not evidenced	80½ hrs. in 7 mos.	47
26	Not indicated	Not indicated	26	Not evidenced	3 hrs. in 1 wk.	26
27	Not evidenced	Not evidenced	Not evidenced	Not evidenced	19 hrs. in 3 wks.	27
Not indicated	Not indicated	Not indicated	Not evidenced	28	5 hrs. in 2 wks.	28½
Not indicated	29	Not evidenced	28½	29	10½ hrs. in 4 wks.	30½
34	33	34	Not evidenced	33	48 hrs.	35
37	37	Not evidenced	38	Not evidenced	149½ hrs. in 10 mos.	43
Not evidenced	Not indicated	Not indicated	33	Not evidenced	3½ hrs. in 4 days	33
33⅔	33	34	33	34	19 hrs. in 4 wks.	34
Not indicated	35	Not evidenced	36	Not evidenced	44 hrs. in 8 wks.	36
48	48	Not evidenced	48	Not evidenced	26 hrs. in 4 wks.	48

Orthopaedic Center from 1947 to 1956 was 306. One hundred fifty-two of these patients had involvement of the upper extremities. Of that group, twelve patients, four years of age or younger, with anomalous or absent upper extremities were selected for this study (Table I). Four were boys and eight were girls. There were nine congenital upper-extremity amputees, with a total of eleven affected limbs. There were three traumatic amputees who had three limbs involved. There were a total of fourteen involved upper extremities in twelve patients four years of age or younger. The youngest child to be fitted with a

prosthesis was five months old, and the oldest child at initial fitting was forty-seven months. The average age of fitting was 23.5 months. The sites of amputation were eight below the elbow, two elbow disarticulations, three above the elbow, and one shoulder disarticulation.

A study of motor development in the infant, recorded by Gesell, indicates that palmar prehension is used primarily until the child is approximately eighteen months old. Some coarse grasping then becomes apparent, but a leading hand is not well developed, and tremor appears with intention. Combined pronation, supination, and wrist flexion and extension are poorly, if at all, used in total hand function at this age. With these functional patterns used as design criteria, non-standard upper-extremity prostheses were constructed for the very young child (Figs. 1 and 2). Basically, these prostheses consisted of a laminated plastic socket of a length sufficient to make the affected extremity as long as the unaffected extremity. Since palmar prehension was the primary functional requirement, no specific terminal device was utilized. The prosthesis was made concave on the volar aspect in order to facilitate bilateral palmar prehension. Later this passive unit was split (Fig. 2) to permit the holding of crackers, suckers, and toys that were flat or thin enough to be placed in the split of the socket. Early in the program, molded solid-rubber hand-shaped mittens were used. Most recently, a plastic hand-shaped mitten with some flexibility has been utilized (Fig. 3).

In patients with below-the-elbow amputations (the most common), leather hinges, a half cuff, and a figure-of-eight harness were used. In the group of above-the-elbow amputees, a prosthesis with a rigid elbow, flexed to 135 degrees and suspended by a figure-of-eight harness, was used. The rigid-elbow prosthesis was decided upon in the very young because it was not felt that these children would satisfactorily utilize a control harness to produce flexion of the elbow. Further, the addition of this control harness with an elbow joint would have made the harnessing more complicated and the prosthesis heavier. In the patient with a shoulder disarticulation, a laminated plastic shoulder cap was fitted, and a standard forearm piece with a passively controlled elbow lock was utilized. This patient had a bilateral condition, and it was necessary to develop a shoulder cap for the opposite side in order to produce satisfactory balance. Initially no prosthesis was applied to the shoulder cap on the contralateral side (Fig. 4). Experience has demonstrated that in the very young child where bone is obscured by superfluous fat pads, satisfactory retention of the figure-of-eight harness was facilitated by a strap across the chest (Fig. 3). As the patient matured and adequate harness fixation could be obtained without this strap, it was omitted from the prosthesis.

In each patient fitted, the situation was discussed in detail with the family. It was explained to them that we were fitting their child earlier than was customary, and the results of such early fitting could not be predicted. In addition, the family was told that it would be necessary for the child to have an indeterminate period of in-patient supervision to promote satisfactory prosthetic fit and comfort, and for observation of the child's reaction to the prosthesis. In all instances there was good cooperation and acceptance by the family.

Following an out-patient examination, the patient was returned home until the prescribed limb was made. Then the patient was observed in the out-patient department with the new limb. When it was found to be satisfactory, the patient was admitted to the Mary Free Bed Children's Hospital and Orthopaedic Center for variable periods of training and observation. While in the hospital, the child was treated by both physical and occupational therapists. The amount and character of the training varied with the age of the patient. If the patient was very young, he was simply retained under supervision until prosthetic comfort and tolerance were obtained. Very little could be done in the way of specific training, but as frequently as possible the patient was encouraged in play activities, and an effort was made to develop play activities that would stimulate bilateral

palmar-prehension patterns. In the next age group (twelve to eighteen months), an attempt was made to break the child of previously established poor prehension patterns. Basically, this consisted in attempting to make the child do functional tasks with his upper extremity at a normal arm's distance away from the body, rather than reverting to the previously learned pattern of bringing all two-handed function into the range of the short or affected extremity. Efforts were made to make the child as aware of the potential of the prosthesis as possible. In order to successfully use an upper-extremity prosthesis, visual clues must become an integral part of function. This cannot be explained to children, but by utilizing functional activities that are sufficiently interesting to attract the child's attention, it is believed that the visual clues for good operation of the prosthesis may be at least improved, if not initiated. Every effort was made not to overtrain the child. It would seem unnecessary to point out that we should not attempt to make the handicapped child perform at a level higher than a normal child of the same age. It was found that this had to be continually emphasized to therapists when the program was initiated. If the child showed any promise, the therapists in their enthusiasm tried to overtrain the child.

As soon as prosthetic tolerance and acceptance had been established and the child had developed some awareness of the potentiality of the prosthesis, the patient was discharged. Prior to discharge, the therapists had a conference with the family and a definite program of home training was outlined. Frequent, out-patient follow-up examinations with careful interviews with the family were maintained. In this way, the use of the prosthesis, its acceptance, and evidences of developing motor patterns were noted. As rapidly as the patients seemed to desire pinching and grasping as opposed to palmar prehension, the immovable temporary prosthesis was converted to a nearly standard prosthesis and a two-fingered hook with a voluntary opening was added as the terminal device. Two types of prostheses were used; one was the standard polished aluminum, rubber-lined, two-fingered hook with a voluntary opening (Fig. 5), and the other was a plastisol-dipped, two-fingered hook with a voluntary opening (Fig. 6). The plastisol-dipped hook was used with the hope that it would be less dangerous for a small child to wear, and would facilitate cleaning by the parents.

Early in the course of this clinical experiment, the enthusiasm of the doctor, prosthetist, and physical and occupational therapist stimulated early conversion from an immovable temporary prosthesis to one with a functional terminal device. While these patients were under careful in-patient supervision, they could be trained to open and close the terminal device on direction, and they could learn to utilize it in a functional manner under direction. It was soon observed, however, that most children under the ages of twenty-four to thirty months did not retain this purposeful grasp-and-release pattern at home after they were discharged. They retained the ability to open and close the terminal device when given specific directions to do so, but they failed to initiate spontaneous purposeful use of the full potentials of the terminal device.

A careful review of Table I will reveal the age of fitting, acceptance, development of functional pattern, and the period of in-patient training necessary in each specific case. This chart further reveals the age at which the child was converted, if he was initially fitted with a temporary prosthesis. The period of in-patient training was excessively long for some patients. Since there was no previously recorded similar investigation, an effort was made to retain these patients for as long as there was improvement in their functional patterns. Recently, because of increasing experience, the in-patient period has been reduced.

In all cases there was good, nearly immediate prosthetic acceptance and tolerance. Once the harness and prosthesis had been adjusted satisfactorily and produced no discomfort, the patient wore the device for all of his waking hours. Functional patterns with both hands were quite rapidly learned, and once learned became automatic and seemed to mature in proportion to the child's increasing age. The temporary prosthesis was used primarily for pushing, pulling, bilateral palmar prehension, and as a weight to hold down

objects which were being manipulated by the opposite upper extremity. Weight-bearing on the prosthesis in creeping has been observed. The split in the temporary prosthesis and the web between the thumb and palm of the mitten-type terminal device were only very occasionally used by the patient for holding objects. In general, the terminal device was of value in a passive manner; the members of the family or the therapist could place an object in it and the patient would continue to carry the object. Only a small percentage of the patients initiated holding objects in the terminal device. It is believed that this does not represent a defect in the design of the prosthesis for at the age at which it is fitted (under twenty-four months) the patient has very little use for purposeful unilateral pinch or grasp prehension.

Beyond the age of twenty-four to thirty months, all patients fitted with a terminal device with an active voluntary opening tolerated the equipment satisfactorily. The addition of a single-control cable system did not produce any discomfort or rejection of the prosthesis, and satisfactory understanding of the operation of the terminal device was quite readily learned. There were variations as to how soon patients spontaneously utilized the terminal device for pinch or grasp prehension. Again, this was interpreted as indicating variations in development in the motor functional pattern, and was not believed to reflect defects in the prosthesis. It became evident from these studies that there was a variation in the age at which children develop purposeful grasp and release, just as there is a variation in the age at which children develop independent walking patterns. This seems to be a highly individualized physiological variation in motor development. It may be varied by very narrow ranges by intensive training, but it is believed that the gains obtained by such intensive training are of very little practical functional value. Our current practice is to wait until the child evidences a desire for purposeful grasp and release, then fit him with an adequate terminal device and give him whatever training is necessary so that he may master the mechanics of prosthetic grasp and release. Satisfactory development of this motor pattern is stimulated by proper toys and play activities.

CONCLUSIONS

1. Prosthetic tolerance can be obtained in children as young as five months.
2. Functional patterns involving both hands at a normal distance from the body can be obtained and are facilitated with early upper-extremity limb-fitting.
3. In the very young (under twelve months), any type of passive terminal device can be used. In this series, the plastic mitten type seemed to best fulfill the requirements.
4. Parental acceptance of early fitting has been excellent.
5. Motor skills cannot be developed beyond the individual's level of motor maturation. Early fitting of a prosthesis does not speed up this physiological maturation process.
6. Purposeful grasp and release utilization of an active terminal device can seldom be developed under twenty-four months of age, and is usually not well developed until thirty months of age.
7. Psychic influence of early prosthetic fitting cannot be evaluated at this time.
8. Masking of the sensory function of the amputated or deformed extremity cannot be evaluated at this time.

NOTE: The assistance and encouragement of George T. Aitken, M.D., and Charles H. Frantz, M.D., Directors of the Area Amputee Center, are gratefully acknowledged.

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Arthrochalasis Multiplex Congenita

Congenital Flaccidity of the Joints

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The authors had the opportunity to observe some patients with congenital flaccidity of the joints—a clinical entity that has been largely ignored in orthopaedic literature. The interest of the senior author in the subject was stimulated in 1951, when, upon studying a group of patients with atypical congenital dislocations of the hip, he found one, in contrast to the rigidity observed in the arthrogrypotic type, who exhibited bilateral congenital dislocation associated with a general hyperlaxity of most of the other joints. The term *arthrochalasis multiplex congenita* was suggested since this sums up the leading clinical characteristics of the condition, namely, multiple articular flaccidity of congenital origin.

Upon reviewing the literature, one is astonished to find how little attention has been given to the orthopaedic aspects of this interesting entity. Nearly all reports have dealt principally with hyperelasticity of the skin, *cutis laxa* or *cutis hyperelastica*. The coincidental presence of hyperlaxity of the joints was considered only one manifestation of a general anomaly of the elastic tissue.

Margarot and associates, Schulmann and Levy-Coblentz, Miget, LeCoulant, and others drew attention to the condition referred to as Ehlers-Danlos syndrome. According to Margarot, the syndrome is characterized by hyperelasticity of the skin, hyperlaxity of the joints, fragility of the skin, and pseudotumors of the skin following trauma. The condition is frequently hereditary and is sometimes associated with other anomalies, such as hernia, spina bifida, and flat-foot. It was assumed that abnormal structure of the connective-tissue bundles and the elastic fibers existed.

Rocher had the opportunity to observe a patient from the age of eight months to twenty-one years. His report dealt with a patient in whom joint involvement predominated. This patient had hyperelasticity of the skin and almost complete hyperlaxity of the joints, giving the impression of rubber joints. The muscles appeared reduced in volume; the ligaments, capsules, and tendons, elongated; the aponeuroses hypoplastic and, particularly in the regions of the hands and feet, hardly developed. There was subluxation of the hip and knee. Although muscle power was retained, walking was difficult. There were no disturbances of ossification. Rocher interpreted the syndrome as mesenchymatous dystrophy.

The first paper to appear in the American literature was written by Tobias, who in 1934 reported a case of Danlos syndrome associated with congenital lipomatosis.

In 1936, Ronchese described three patients with the syndrome and stressed the importance of one of the symptoms, the fragility of the skin, over the others. Two of his patients had minor hyperflexion of the joints, especially noticeable in the fingers and toes; the third patient showed no abnormality of the joints. He called the condition dermatorrhexis.

Cases of Ehlers-Danlos syndrome were subsequently reported by Murray and Tyars, Benjamin and Weiner, Taylor, and Kanof. For the most valuable contribution we are indebted to Johnson and Falls who, in 1949, presented a comprehensive study of two patients. They discussed the clinical, pathological, and genetic aspects. In these two cases, as in all other reports on this condition to date, the cutaneous symptoms predominated, while the joint symptoms appeared to have little consequence.

Simple hypermobility, called hyperflexion or hyperextension of the joints or double joints, may occur as an isolated finding without involvement of the skin, as reported by Key, Sturkie, and Sutro. Key, in 1927, discovered two brothers who were admitted for treatment of bilateral club-foot. It was noticed that both patients had a range of motion in the joints definitely greater than the normal. A third brother had had several dislocations of the patella; however, the dislocations had always been easily reduced. The condition had appeared spontaneously in the father and was transmitted to his sons, but not to any of his daughters. Sturkie's report is mainly concerned with the analyses of two family histories. From his study one is apt to suspect a maternal influence in the transmission of the anomaly since in both cases it was transmitted through the females. Sutro reported five patients with primary hypermobility of the joints of the upper and lower extremities associated with recurrent effusions of the ankle and knee joints without trauma. It seemed that certain overly long articular capsular and ligamentous tissues were probably the cause of the hypermobility. In these five cases, no evidence of generalized hyperelasticity of the skin was noticed.

In a recently published report on hereditary disorders, McKusick described a man, forty-seven years old, with a history of congenital dislocation of the right hip, treated by means of immobilization in a spica cast at the age of two years and by several operations when he was a young man. He also underwent surgery for the repair of bilateral inguinal hernia. There was also hiatus hernia. Two operations were performed on the knee for presumed trauma following an automobile accident. At the age of twenty-seven years, relaxation of the radiocarpal joint necessitated the application of a cast. McKusick felt that hyperelasticity of the skin, although present, was a subsidiary feature in this patient.

From these reports we feel that enough material has been published to justify the definition of simple hypermobility of the joints without involvement of the skin as an independent articular disorder apart from the typical Ehlers-Danlos syndrome.

CASE REPORTS

Five cases of congenital multiple articular flaccidity have been encountered at the Hospital for Special Surgery during the years 1951 to 1956. In all of these cases except one, the flaccidity of the joints appeared without involvement of the skin. The skin remained within the limits of normal elasticity.

CASE 1. P. G., a white boy, was first seen at the age of eight months. He had previously been in the care of a private physician. His birth followed a normal eight-month pregnancy, but the obstetrician noticed at birth that all his joints displayed excessive flexion and extension. He had been treated in a brace before being seen at the hospital.

Family history: It is reported that the divorced father had some hyperextension of the joints in his youth, but he was not examined. The patient's mother was examined. She had an olive complexion but no hyperextension of her joints.

Physical examination: The patient was a well developed, well nourished boy with a slight degree of hydrocephalus. He had an olive complexion, and his skin, folded about the hands and legs, was of moderate hyperelasticity. There was marked hyperextension of the joints. He had flexion dislocation of the metacarpophalangeal joint of the right middle finger. It could be reduced easily. In the metacarpophalangeal joints there was 90 degrees of active hyperextension. The proximal and distal interphalangeal joints extended to 90 degrees on both hands. The elbows showed hyperextension and hyperflexion. The angle of greatest extension was 195 degrees, and the angle of greatest flexion was 15 degrees. The shoulders showed increased internal and external rotation. Both hips were completely dislocated with marked push-pull instability. They could be reduced easily without any reduction phenomenon and then redislocated immediately. The knees showed hyperextension. The angle of greatest hyperextension was 95 degrees, and the angle of greatest flexion was 35 degrees. There was severe valgus deformity of both feet, flattening of the longitudinal arches, prominence of the tali on the medial borders of the feet, and plantar flexion of the tali. All toes showed hyperextension at the distal and proximal interphalangeal joints. The patient also had had an inguinal hernia. There was good muscle tone. The deep tendon reflexes were equal and active, and there were no pathological reflexes.

Roentgenographic examination: Roentgenograms showed bilateral dislocation of the hips. The acetabula were well developed and the femoral heads were at a wide distance from the acetabula.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. P. G. Roentgenogram reveals bilateral congenital dislocation of the hip in an eight-month-old boy. Significantly the acetabula are well developed and the femoral heads widely displaced from the acetabula due to the elongation of the capsule and ligaments. (Reprinted by permission from "Congenital Dislocation of the Hip," p. 23 by Julius Hass. Springfield, Illinois, Charles C. Thomas, 1951.)

Fig. 1-B: Photograph of the same boy at the age of ten years shows active hyperextension of the metacarpophalangeal joints.

Fig. 1-C: Roentgenogram made of the hips of the same patient at the age of ten years, eight years after closed reduction. This dislocation is now well reduced and stable.

FIG. 1-C

Laboratory examination: Urinalysis revealed no sugar, no albumin, and no acetone. Blood studies gave a white blood cell count of 7,800 and a red blood cell count of 4,460,000; the differential count revealed 60 per cent polymorphonuclear leukocytes, and 40 per cent lymphocytes. Hemoglobin was 16 grams per 100 cubic centimeters.

Treatment and course: The dislocation of the hips was reduced when the patient was eight months old and the hips were immobilized in a plaster cast in 90 degrees of flexion and 90 degrees of abduction for two years. He then spent a year and a half in a Hass abduction bar. He returned to our institution two years later with relatively good stability in both hips. Severe rocker-bottom deformity of the feet developed and the patient was fitted with molded leather calcaneal braces. As he grew older, he continued to achieve greater stability, but excessive motion in all joints persisted. His inguinal hernia was repaired at another hospital, but recurred.

CASE 2. W. Q. was a ten-year-old Spanish-speaking boy complaining of limp, spinal curvature, and pain in the left hip and knee.

History: At the age of one year, when he first walked, his mother noticed that he had curvature of the spine and walked with a limp. There was increasing pain in the left knee and fatigue upon exercise. The interpreter denied familial predisposition, and the patient's parents were not examined.

FIG. 2-A

FIG. 2-B

FIG. 2-C

Fig. 2-A: Case 2. W. Q. Photograph shows a ten-year-old boy with scoliosis and hypermobility of other joints. He has severe right dorsal, left lumbar scoliosis and marked left genu valgum.

Figs. 2-B and 2-C: Photographs show passive hyperextension of finger joints.

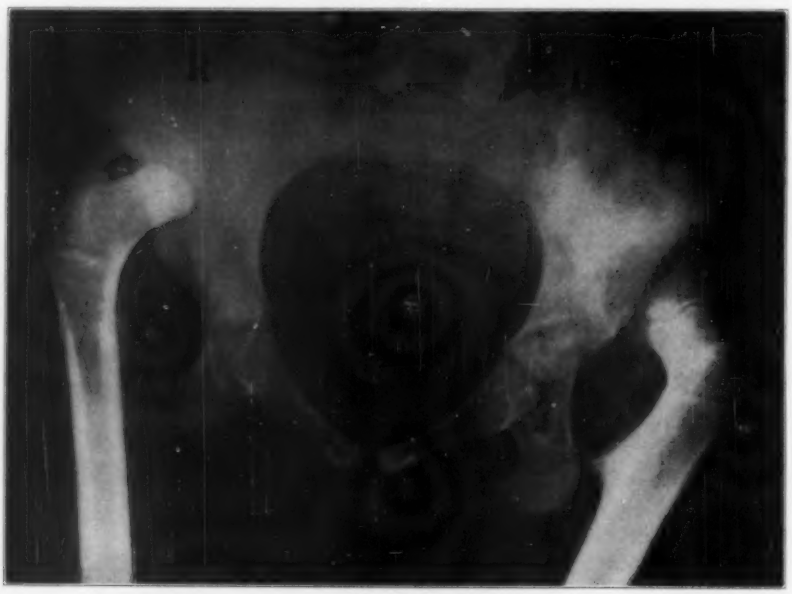

FIG. 2-D

Fig. 2-D: Roentgenogram of the pelvis reveals congenital dislocation of both hips.

Physical examination: Physical examination revealed a well developed but grossly deformed boy who walked with a severe waddle and a limp, caused by extremities of unequal length. His general physical condition was normal except for his extremities and spine. He had an olive complexion and his skin was soft, but not hyperelastic. There was severe hypermobile unfixed right thoracic, left lumbar scoliosis with razorback deformity. Both shoulders had a normal range of motion. There was bilateral dislocation of the radial heads at the elbow with limitation in extension to 160 degrees but flexion increased to 20 degrees. At the wrists, both ulnae were dislocated. There was extreme flexion and extension in all finger joints. Distal and proximal interphalangeal joints could be hyperextended to 225 degrees. The thumb touched the wrist in

extension easily. Both hips were dislocated in extension; external rotation was 20 degrees and internal rotation was 90 degrees. The angle of greatest flexion in both hips was 90 degrees and the angle of greatest extension was 150 degrees. The left knee was dislocated and the tibia externally rotated 90 degrees. Only 10 degrees of motion was possible, from 115 degrees of flexion to 125 degrees of extension. The right foot showed severe valgus deformity of the heel and rocker-bottom deformity. The talus was flexed plantarward and was prominent along the medial border of the foot. The left foot was similarly deformed.

Roentgenographic examination: There was right thoracic, left lumbar scoliosis. The vertebral bodies were wedged at the apex of each curve. Both radial heads were dislocated posteriorly. The left knee showed severe malformation of the lower femoral epiphysis and was dislocated laterally and posteriorly. The tibia was rotated 90 degrees externally. Both feet showed severe plantar-flexed tali, flattening of the longitudinal arches, rocker-bottom deformity, and severe abduction of the fore part of the foot.

Laboratory examination: The urine was clear with specific gravity of 1.010. There was no sugar or acetone. Kline test was negative. There was no acid. Blood studies revealed 4,250,000 red blood cells; 12,000 white blood cells; 76 per cent polymorphonuclear leukocytes; 22 per cent lymphocytes; and 2 per cent eosinophils.

Treatment and course: Because of increasing scoliosis, the patient was placed in bed in a corrective plaster jacket for two years. Spine fusion was done after correction of the deformity and the spine was well stabilized. He also had a triple arthrodesis of the left foot. At the time of writing he was a senior in high school, had severe hyperelasticity of his joints, and walked with a cane.

Two of the five patients in this study had a right thoracic, left lumbar scoliosis. In this patient, first seen at the age of ten years, the upper curve progressed from 63 degrees to 81 degrees, and the lower curve from 55 degrees to 100 degrees. The second child (Case 5) has had no treatment as yet.

CASE 3. P. G., a ten-month-old white girl, was first seen at the Hospital for Special Surgery because of bilateral dislocation of the hip and knee.

History: She was born following a normal nine-month pregnancy. At birth, the obstetrician noticed that she had joints that flexed and extended more than the normal. She was placed in Buck's traction for four weeks and then a brace was applied over both knees. Father and mother were both twenty-eight years old and denied similar familial defects.

Physical examination: General medical examination revealed normal conditions. She had an olive complexion, and her skin was soft but not hyperelastic. The hands showed marked hyperextension. The angle of greatest extension of the interphalangeal joints was 225 degrees. The thumb easily hyperextended to the arm. The elbows hyperextended to 200 degrees. The hips showed bilateral push-pull instability with a positive reduction phenomenon. There was 25 degrees of genu recurvatum bilaterally. At the knee joint there was 70 degrees of abduction and 30 degrees of internal rotation. The knees were dislocated and the femoral condyle was posterior to the fibula. The feet were quite flat on weight-bearing. There was prominence of the right talus along the medial border with plantar flexion. The patient could flex her straight leg to her chest easily. No abnormal neurological findings were noted.

Roentgenographic examination: Dislocation of both hips and both knees was noted. Roentgenograms of the feet revealed plantar flexion of the tali.

Laboratory examination: Urinalysis was normal and the hemoglobin was within normal limits.

Treatment and course: Closed reduction of the dislocation of both hips was done. Open reduction of the dislocation of both knees and bilateral quadriceps lengthening were done at the age of one year. The patient had persistent bilateral genu recurvatum. When she was seven years old, a supracondylar osteotomy was performed to correct both genu valgum and genu recurvatum. When she was re-examined in 1957, she walked quite well but had extremely flat feet with plantar-flexed tali. One hip was stable; the other hip had redislocated. Open reduction was contemplated but had to be postponed.

CASE 4. G. H., a five-year-old boy, complained of painful flat-foot and weakness of the right knee.

History: The patient was originally treated in Puerto Rico for bilateral club-foot and had a series of four or five casts on both feet before his first birthday. Since that time he had flat feet and had pain over the medial borders of his feet. He was seen recently at another hospital where navicular pads were recommended. Since he began to walk, he has had frequent locking of his right knee. There is no history in the family of a similar condition.

Physical examination: Physical examination revealed an alert Spanish-speaking boy. He had an olive complexion and his skin was stretchable, but not hyperelastic. An incision from an operation for hernia in the right inguinal region was well healed; the scar was not stretched or thin. His chest had good expansion. There was prominence in the mid-clavicular line of the ribs and a very shallow sternum. Examination of his shoulders revealed normal internal and external rotation. The elbows were hyperextended 15 degrees. He could dorsiflex his thumbs to his wrist. The passive range of motion of his proximal and distal interphalangeal joints was 90 degrees of flexion to 235 degrees of hyperextension. His hips were stable but internal and external rotation were both increased to 90 degrees. He could place his heel in his umbilicus. The knees were stable, but had an increased range of motion. Maximum extension was 200 degrees; flexion, 25 degrees.

FIG. 3-A
(*See page 669*)

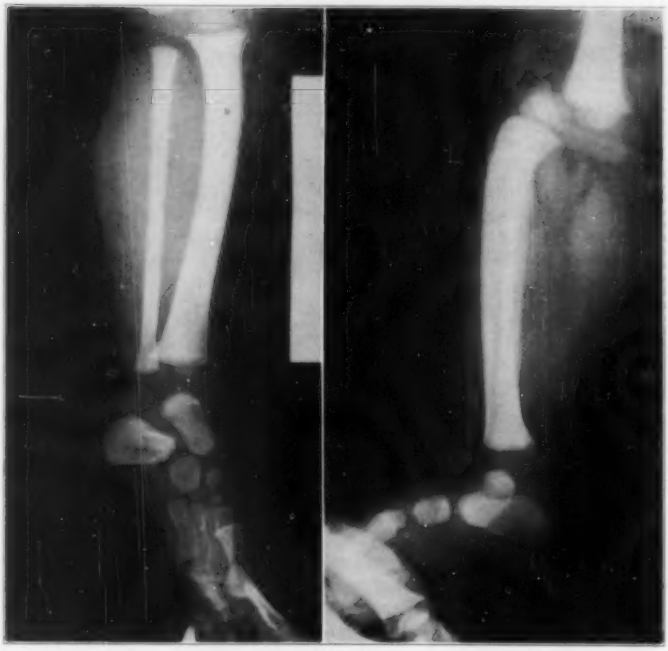

FIG. 3-B
(*See page 669*)

Fig. 3-A: Case 3. P. G. Photographs show a ten-month-old girl with bilateral dislocation of the hips and excessive laxity of all joints. The deep gluteal folds and bilateral genu recurvatum are shown.

Fig. 3-B: Roentgenograms of both knees and feet show anterior dislocation of the tibia and plantar flexion of the talus.

FIG. 4-A

FIG. 4-B

Case 4. G. H. Photographs demonstrate a five-year-old boy with general laxity of the joints and recurrent dislocation of the right patella. The increase in the range of motion of the elbow in both flexion and extension is shown.

The right patella could be easily dislocated laterally with minimal pain. Examination of the feet revealed approximately 10 degrees of calcaneovalgus and flattening along the longitudinal arches. The head of the talus was almost touching the plantar surface of the foot.

Roentgenographic examination: Roentgenograms revealed pigeon-breast deformity and genu recurvatum of 15 degrees of the right knee. There was rocker-bottom deformity of the right foot.

Laboratory examination: Urinalysis was normal and the hemoglobin was within normal limits.

Treatment and course: Bennett's reefing of the medial capsule of the knee was performed, and a specimen of the capsule was excised for histological examination. The specimen was normal except for a few areas of necrosis that had probably resulted from the trauma of dislocation. In six months of postoperative observation of the patient there was no recurrence of his disability.

CASE 5. V. D., a two-year-old boy with dislocation of the left sternoclavicular joint and deformity of the feet.

History: Delivery was by breech presentation; the child's birth weight was seven pounds, eight ounces. It was noted at birth that he had excessive motion in his joints and a club foot and a club hand on the left side. The patient had had a series of approximately six plaster casts and splints on the left foot. He had had a delayed development; at six months he did not crawl, raise his head, or roll over without assistance.

Family history: His mother was twenty-eight years old, his father thirty-two. The parents are first cousins and the grandparents are first cousins. There was no similar disease in the family.

Physical examination: Physical examination revealed an alert well developed child with a head somewhat larger than normal; the anterior fontanel measured four by four centimeters. He had an olive complexion and his skin was somewhat stretchable but not abnormally so. His shoulder joints were stable but the elbow joints were hypermobile. On pronation of the forearm there was a creaking at the distal radio-ulnar joint. The range of motion of the elbow was 185 degrees of extension to 20 degrees of flexion. There was marked hyperextension of the fingers and wrist. He was able to touch his fingers and thumb to the dorsum

FIG. 5-A

FIG. 5-B

Case 5. V. D. Photographs show hands of a two-year-old boy with marked scoliosis, dislocation of the sternoclavicular joint, and hypermobility of other joints. Note the extreme hyperextensibility of the finger joints.

of his forearm. There was 35 degrees of hyperextension in each interphalangeal joint and these joints could be subluxated manually. There was left lower fixed thoracic scoliosis. The hips were stable but he had hyperflexion to a degree rendering it possible for him to flex his thigh to his abdomen with his knee straight. He could hyperextend both knees 30 degrees. His feet were quite unstable. On weight-bearing they everted and the tali were flexed plantarward and touched the floor. The mid-tarsal and tarsal joints could hyperextend as well as the toes. The boy was able to walk with the aid of short braces and showed good muscle strength in both his upper and lower extremities. The deep tendon reflexes were equal and active. He had no pathological reflexes.

Roentgenographic examination: Roentgenographic examination revealed an occult spina bifida at the level of the fifth lumbar and first and second sacral vertebrae; reduced muscular shadows and right thoracic, left lumbar scoliosis; severe hyperextension of the knees, wrists, and fingers.

Laboratory examination: The urine was clear and had no sugar or acetone. The hemoglobin was thirteen grams per 100 cubic centimeters; there were 10,000 white blood cells. In the differential count there were 76 per cent lymphocytes and 24 per cent polymorphonuclear leukocytes.

Treatment and course: This patient's condition presented a difficult diagnostic problem. His condition first appeared to be possible myatonia congenita; however, electromyograms failed to reveal lower motor neuron damage. His muscle development at the end of two years had progressed with increased strength and, at the time of writing, was approaching normal. The child who could not turn over alone at the age of eight months was able to walk with the aid of short braces and physical therapy at the age of two years.

The physical findings in the five patients are listed in Table I.

FINDINGS

On the basis of our observations, we have found the following features to be characteristic of this condition.

Arthrochalasis may be observed at various ages. Usually it is noticed in early childhood, but the origin is undoubtedly congenital. There is no sex predominance. The condition may involve all of the joints, particularly those of the fingers, toes, wrists, elbows, shoulders, hips, and knees, and is usually symmetrically distributed. The condition is certainly heredofamilial in some instances and is often associated with other congenital anomalies, such as hydrocephalus, spina bifida, hernia, or calcaneus.

There may be different degrees of the condition, from moderate hyperextension of the joints to severe flaccidity, subluxation, and complete dislocation of the joints. Dislocation usually occurs in the hip, knee, metacarpophalangeal joints, or sternoclavicular joint. While complete involvement of all joints is rare, mild hyperextension of the metacarpophalangeal and metatarsophalangeal joints is a common occurrence. Such cases may be defined as an aborted form of the disease.

Many mild cases undoubtedly go unrecognized. In others, the patient may be considerably handicapped due to the dislocation of the joints and the resulting lack of stability. Physical examination may reveal a mobility of the affected joints considerably beyond normal limits with the result that the limbs can often be placed in grotesque positions.

The most characteristic feature is the ability of the patient to hyperextend the finger joints; this is apparent in all cases of arthrochalasis. It may reach such a degree that the finger tips can touch the dorsum of the wrist or the thumb may be extended to the dorsum of the forearm. There may be hyperextension or hyperflexion of the elbow so that the wrist can touch the shoulder. There also may be hypermobility of the spine associated with a severe flexible scoliosis. (There were three cases of scoliosis in our group of five patients with arthrochalasis.) The patient may stand with the knees abnormally hyperextended. Dislocation of the hips is not uncommon in this condition (occurring in three of our five cases). Also dislocation of the knee and elbow joints may be observed. In all our five cases, we noted severe flat-foot deformity with pronounced plantar-flexed tali and rocker-bottom deformity of the sole of the foot, and with extreme hypermobility of all foot joints, especially noticeable on weight-bearing. This is undoubtedly the result of the extensive weakness of the ligaments and lower resistance to weight-bearing.

The complexion is usually olive and the skin, soft, but otherwise normal. It is not hyperelastic as in typical Ehlers-Danlos syndrome. The muscles are atrophic, but muscle power is only slightly diminished. Reflexes are normal. All biological tests give results within normal limits and the blood is normal. The Wassermann test is negative.

In only one patient in our group (Case 4) was a joint capsule studied. Pathological examination revealed normal tissue except for a few areas of necrosis, probably resulting from the trauma of dislocation.

Roentgenograms show a normal bone structure with no signs of ossification or decalcification. Dislocations of the joints are distinctly outlined. Significantly, in dislocation of the hip, the acetabula may appear well developed, while the femoral heads are widely displaced in distance from the acetabular floor due to the elongation of the capsule and ligaments.

DIAGNOSIS

The distinctive features of the condition leave little chance for difficulties in diagnosis and we are sure that more cases will be recognized as arthrochalasis when physicians become better acquainted with the symptoms of the condition. Partial or complete laxity of a joint may be caused by a paralytic condition, especially poliomyelitis. In arthro-

TABLE I

TABULATION OF PERTINENT PHYSICAL FINDINGS

Case	Age	Sex	Skin	Spine	Clavicles	Shoulders	Elbows
1. P. G.	8 months	M	Moderately hyper-elastic	Lordosis	Stable	Stable	Hyperextensible
2. W. Q.	10 years	M	Normal	Right dorsal, left lumbar scoliosis	Stable	Shallow glenoid cavity	Dislocated
3. P. G.	10 months	F	Normal	Stable	Stable	Stable	Stable
4. G. H.	5 years	M	Normal	Stable	Stable	Stable	Stable
5. V. D.	2 years	M	Normal	Right dorsal, left lumbar scoliosis	Sterno-clavicular dislocation	Stable	Hyperextensible

chalasis, the characteristic initial stage of poliomyelitis is missing, and there is absence of nerve disorders.

Another disease which eventually may be confused with arthrochalasis is myatonia congenita which is characterized by paralysis of the arms and legs, and particularly by atrophy of the intrinsic muscles. It is an acute and progressive disease; the electric irritability and reflexes are definitely diminished and more closely resemble the signs of poliomyelitis.

Hypermobility of the fingers may suggest the possibility of arachnodactyly. This is a rare congenital condition characterized by long hands and feet and general muscular weakness. The excessive length of the fingers and the toes is particularly striking and is diagnostic.

Laxity and subluxation of the metacarpophalangeal joints are often seen in the course of rheumatoid arthritis. Usually the symptoms of rheumatoid arthritis are too significant to be misleading. The joints in rheumatoid arthritis show fusiform swelling and there is tenderness of the joints that does not exist in arthrochalasis.

It may be difficult to differentiate dislocation of the hip in arthrochalasis from typical congenital dislocation of the hip. The latter is characterized by acetabular dysplasia. In arthrochalasis, the acetabula are primarily well developed and the femoral heads are usually at an extreme distance from the acetabula. In addition, the dislocation in arthrochalasis is combined with general hyperlaxity or dislocation in other joints.

Arthrochalasis represents, to some extent, the antithesis of arthrogryposis multiplex congenita. The characteristic feature of arthrogryposis is general articular rigidity associated with fixed deformities such as club-foot, club-hand, and contractures of the elbow, knee, and hip joints. The primary anomaly is in the muscles which display degenerative ischaemic-like changes with secondary shrinkage of the capsular apparatus.

According to McKusick, loose-jointedness occurs also in other hereditary disorders. In differential diagnosis, especially in children, cerebrocortical degeneration or mongolism, cretinism, rickets, and non-specific cachexia must be kept in mind.

ETIOLOGY

Little is known concerning the etiology of arthrochalasis except that the condition is congenital and is frequently heredofamilial. Johnson and Falls in their studies of the Ehlers-Danlos syndrome report a family pedigree of 123 persons, of whom twenty-one men and eleven women had the syndrome. The pedigree of the reported kindred suggests a definite inheritance pattern of transmission of the anomaly.

In Key's double-jointed family, a sex-linked inheritance was suggested since the dis-

TABLE I

TABULATION OF PERTINENT PHYSICAL FINDINGS

Wrists	Fingers	Hips	Knees	Feet	Toes
Hyperextensible	Hyperextensible	Dislocated	20 degrees recurvatum	Plantar-flexed tali	Hyperextensible
Dislocated	Hyperextensible	Dislocated	Left dislocated	Plantar-flexed tali	Hyperextensible
Stable	Hyperextensible	Dislocated	Dislocated	Plantar-flexed tali	Hyperextensible
Hyperextensible	Hyperextensible	Stable	Right patella dislocated	Plantar-flexed tali	Hyperextensible
Hyperextensible	Hyperextensible	90 degrees internal and external rotation	30 degrees hyperextension, subluxation	Plantar-flexed tali	Hyperextensible

order occurred only in males. From Sturkie's study, however, it is obvious that the transmission is irregular since in his patients the anomaly was transmitted only through the females. McKusick is inclined to believe that the disorder is inherited as a mendelian dominant.

In view of lack of factual material, the opinion must remain a hypothesis. It can be assumed that the etiology of the disease is congenital fibrodystrophy, as indicated by Rocher. The initial cause is a diminished resistance of the fibrous and elastic tissues that are elements of the mesenchyma. Benjamin and Weiner and others have regarded the condition as a congenital, constitutional, and developmental mesenchymatous dysplasia. These authors express the opinion that the same unknown disturbance of the mesenchyma, responsible for anomalies of the skin which is of ectodermal origin, causes the changes in the capsules and ligaments of the joints, which are of mesodermal origin.

Further investigation is needed for a proper evaluation of the underlying causes of the condition. An accurate knowledge of the pathological anatomy of these cases would be of greatest help toward solution of this problem and must be the aim of future studies. We believe that the basic defect is not only one of a histological disturbance of the connective tissue, but is an innate chemical inadequacy of the collagen fibers which allows them to stretch. Comparative chemical studies of normal and stretchable connective tissue should be made.

Another question arises as to whether the entity, as described here, may also be related to some forms of recurrent dislocation of the shoulder, patella, metatarsophalangeal joint of the thumb, sternoclavicular or temporomandibular joints, the etiology of which has never been clarified.

This question presents just as many difficulties as the persistent question of the etiology of all recurrent dislocations. In cases of demonstrable congenital heredofamilial origin, the possibility of a genetic connection between habitual dislocation and arthrochalasis cannot be excluded. At any rate, it would seem advisable to examine all patients with recurrent dislocation most carefully from this point of view.

SUMMARY

Arthrochalasis multiplex congenita is a distinct clinical entity characterized by a multiple congenital flaccidity of the joints.

It may be associated with laxity or hyperelasticity of the skin defined as Ehlers-Danlos syndrome, or it may exhibit hypermobility of the joints without involvement of the skin.

The degree of the severity of the condition may vary from mild hyperextension of the

metacarpophalangeal and metatarsophalangeal joints, classified as an aborted form of the disease, to flaccidity, subluxation, and complete dislocation of the joints.

The condition is frequently heredofamilial and is apparently due to a constitutional dyscrasia of the mesenchyma.

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Primary Vitallium-Mold Arthroplasty for Posterior Dislocation of the Hip with Fracture of the Femoral Head

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A number of excellent statistical reviews have been presented on the problems attendant on dislocation and fracture-dislocation of the hip [1,5,9,10,12]. With the exception of Pipkin's review, fractures of the femoral head have not been analyzed separately as concerns treatment. In 1952, one of us [6] reported his experience in treating two fractures of the femoral head with dislocation by primary Vitallium-mold arthroplasty. In addition, it has come to our attention that Smith-Petersen [2] also performed primary Vitallium-mold arthroplasty for fractures of the femoral head with posterior dislocation and was a firm believer in this method of treatment. Badgley also had experience with this procedure and found it satisfactory. Westerborn, in 1954, reported on the use of Vitallium-mold arthroplasty for central dislocation of the femoral head.

Results of treatment of fractures of the femoral head with posterior dislocation are more often unsatisfactory than satisfactory. According to Urist, when the fragment of the femoral head is small and inferiorly placed, accurate closed reduction or excision of the fragment can give good results. Some of the results reported in the literature on this difficult joint injury are given in Table I.

The results reported in the literature and our personal experience with the injury seemed to indicate a need for a departure from conservative care. Closed reduction often

TABLE I

POSTERIOR DISLOCATION OF THE HIP WITH FRACTURE OF THE FEMORAL HEAD

Authors	Cases	Results	
		Satisfactory	Fair or Poor
Stewart and Milford	7	1	6
Thompson and Epstein	11	1	10
Armstrong	5	1	4
Waller	7	1	6

is not possible, and therefore, open reduction weeks after the injury seems unsound. Deferring reconstructive surgery until degenerative changes have occurred with resulting pain, deformity, and wasting of muscles also seems illogical.

MATERIAL FOR STUDY

Eight patients form the basis for this study. In addition, five patients treated by methods other than primary Vitallium-mold arthroplasty were studied. All except one patient were seen at the Mayo Clinic seven days or less from the time of initial injury. The case of one of the thirteen patients was included among the seven cases of fracture of the femoral head reported by Ghormley and Sullivan. The period of study was from 1947 through 1955.

MECHANISM OF INJURY

Each patient was injured in an automobile accident. Although the exact mechanism

* The Mayo Foundation, Rochester, Minnesota, is a part of the Graduate School of the University of Minnesota.

FIG. 1-A

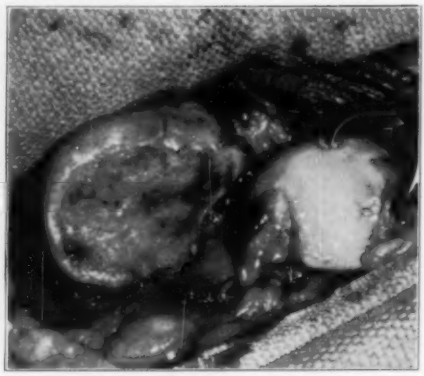

FIG. 1-B

Figs. 1-A and 1-B: The fracture of the femoral head at time of arthroplasty.
Fig. 1-A (Case 3, Table II): The detached fragment involves nearly half of the femoral head.
Fig. 1-B (Case 6, Table II): The fragment consists of at least a third of the femoral head; the detached fragment is still connected to the ligamentum teres.

was not always recorded, the injury in most cases resulted from a force on the knee transmitted along the shaft of the femur to the flexed hip. In two cases it appeared that the knee was pushed to the dashboard and the main force was then transmitted by heavy objects sliding forward against the patient's back. We agree with Waller that these injuries could well be called dashboard injuries, although he used this term mainly to describe posterior acetabular fractures.

FINDINGS AT OPERATION

In all eight cases in which primary arthroplasty was performed, a third to a half of the femoral head was found sheared off at operation. The detached fragment was medially or inferomedially placed, and involved the weight-bearing surface of the femoral head. The gross findings in two of these patients at the time of operation are shown in Figures 1-A and 1-B.

Two of the eight patients had damage to the posterior wall of the acetabulum. In one the fragment was large enough so that fixation with two screws was necessary.

THE PRIMARY ARTHROPLASTY

Primary arthroplasty was performed on an average of four days from the time of initial injury. Usually the delay in treatment was due to the patient's being treated elsewhere and then being referred to the clinic after manipulation had failed to reduce the fracture-dislocation. Stewart and Milford have pointed out that no patient with posterior dislocation of the hip in their series attained a good result if accurate reduction was not attained within twenty-four hours of the injury. We agree with the principle of early treatment behind this statement, and whenever possible we performed the operation soon after the patient's admission to the hospital.

The technique of arthroplasty used in these cases was that outlined by Lipscomb and Barber. The only important modification was that remodeling was limited to the femoral head. As already mentioned, one patient required fixation of the posterior fragment of the acetabulum by screws. In one other patient who had slight comminution of the posterior portion of the acetabulum, the detached fragments were removed, and enough acetabulum remained to provide good stability.

The care after arthroplasty of the hip was the routine care for such patients at the clinic, as described by Bickel and Babb, in all our patients except the one who had had screw fixation of the posterior fragment of the acetabulum. This patient was placed in

FIG. 2-A

FIG. 2-B

Figs. 2-A, 2-B, and 2-C (Case 1): Fracture-dislocation of the right hip.

Fig. 2-A: The fractured fragment involves at least a third of the femoral head.

Figs. 2-B and 2-C: Anteroposterior and lateral views of the right hip eighteen months after injury and Vitallium-mold arthroplasty. (Inset: Fragment removed at the time of operation.)

FIG. 2-C

skeletal traction for six weeks before the usual program was instituted.

RESULTS OF PRIMARY ARTHROPLASTY

The results in the eight patients (Cases 1 to 8) treated by primary arthroplasty are summarized in Table II. The operation was considered successful at the time of follow-up if the patient was completely free of pain, had been able to return to his previous occupation, and had returned to full work in this occupation. Seven were considered to have successful results. Five of the seven considered successfully treated were able to walk without any support. Two patients (Cases 4 and 6) although able to walk without support required support when walking long distances. As noted in Table II, four of the eight patients (Cases 1, 2, 3, and 7) were engaged in what might be classified as heavy labor. One patient was considered to have a poor result. Although pain was not excessive, he was still using crutches or a cane for support and in all likelihood would have to have further surgical treatment. We have preferred to use the terms *successful* and *unsuccessful* to other terms so that the reader may evaluate the degree of success of the operation in each case from the evidence presented in Table II.

TABLE II

POSTERIOR DISLOCATION OF THE HIP WITH FRACTURE OF THE FEMORAL HEAD

Case	Age and Sex		Hip	Interval from Injury to Operation	Pain	Walking with or without Support	Occupation and Return to Occupation	Range of Motion (*Degrees*†)	Result and Duration of Follow-up
1	24	M	R	6 days	None	Walks well without any support	Construction worker; returned to full work	F-E 180–80 Ab-Ad 20–25 ER-IR 20–20	Successful 8½ yrs.
2	46	F	L	12 hrs.	None	Walks well without any support	Waitress; works 10 hours a day; returned to full work	F-E 170–65 Ab-Ad 20–25 ER-IR 20–20	Successful 8 yrs.
3	38	M	R*	4 days	None	Walks well without any support	Truck driver on milk route; returned to full work	F-E 180–85 Ab-Ad 30–30 ER-IR 25–15	Successful 4½ yrs.
4	60	M	L	7 days	None	Walks 1 to 2 blocks without cane; for longer distances uses cane	Salesman; retired this year, still very active at 66	F-E 180–90 Ab-Ad 20–30 ER-IR 15–15	Successful 5½ yrs.
5	59	M	L*	3 days	None	Walks well without any support	Merchant; owns store; returned to full work	F-E 180–60 Ab-Ad 30–30 ER-IR 25–15	Successful 2 yrs.
6	35	M	L	5 days	None	Walks 1 to 2 blocks without cane; for longer distances uses cane; walks about office all day without support	Dentist; returned to full work	F-E 180–90 Ab-Ad 0–20 ER-IR 15–10	Successful 2 yrs.
7	43	M	L	1 day	None	Walks well without any support	Heavy-manual laborer; returned to full work	F-E 180–60 Ab-Ad 30–30 ER-IR 15–15	Successful 26 mos.
8	40	M	L	5 days	Yes	Uses cane or crutch; poor walker	Merchant; has returned to work	F-E 170–90 Ab-Ad 10–20 ER-IR 10–10	Unsuccessful 22 mos.

* Fractures of acetabular rim associated.
† F-E, Flexion-extension
Ab-Ad, Abduction-adduction
ER-IR, External rotation, internal rotation.

In Case 1 (Table II) the preoperative roentgenograms show fracture-dislocation with fracture involving a third of the femoral head (Figs. 2-A, 2-B, and 2-C). At operation, a large fragment was removed from the joint and a Vitallium mold put in place. Eight and a half years from the original injury the patient was working full time as a heavy-construction worker without pain.

The second patient (Case 2, Table II) now works daily as a waitress. She is overweight, but eight years from the time of initial injury she has a good range of motion and is free of pain (Figs. 3-A and 3-B).

All patients in this group have been examined recently by us, as well as by our colleagues in the Section of Orthopaedic Surgery. In our opinion, as well as that of our colleagues, the results obtained by primary Vitallium-mold arthroplasty in these patients are superior to the results usually achieved when Vitallium-mold arthroplasty is performed for conditions such as old degenerative disease of the hip joint.

PATIENTS TREATED BY METHODS OTHER THAN PRIMARY ARTHROPLASTY

During the period under consideration five patients were treated for fracture of the

FIG. 3-A

FIG. 3-B

Fig. 3-A (Case 2): Posterior dislocation of left hip with fracture of femoral head.
Fig. 3-B: Same hip seven and one-half years after operation. Note calcification of the soft tissue about the hip.

femoral head accompanying posterior dislocation by means other than primary arthroplasty. In three of the patients, closed reduction was obtained within twenty-four hours of injury. In one, an accurate reduction was attained between the femoral head and the sliced type of fragment. In the second, seven days after closed reduction of the fracture, the fragment was removed through a Watson-Jones incision without dislocating the joint. Both of these patients have satisfactory results to date and have been followed five years and two years, respectively. The third patient treated by closed reduction within twelve hours of injury eventually came to arthroplasty. In two other patients, with dislocation and fractures involving a third of the femoral head, reduction was by open operation with removal of the fragments seven and thirteen days, respectively, after the injury. The fragments were removed from both patients through a Gibson posterolateral approach. One subsequently came to arthroplasty; the other patient was lost to follow-up but a letter and a roentgenogram made at home five years following operation made it appear that, in all probability, he had a painless ankylosis with the hip in good position.

SUMMARY AND COMMENT

Fracture of the femoral head associated with posterior dislocation is rare. Although our experience is small, we present these cases because in them treatment carried out soon after the injury was more active than in most cases recorded in the literature.

In eight patients with capital fragments involving a third to a half of the femoral head, primary Vitallium-mold arthroplasty has yielded seven satisfactory results. Only four of these patients have been followed for prolonged periods, but, of the remaining, three appear to be repeating the progress of our earlier patients.

Our plan of treatment for these injuries is as follows:

1. Primary Vitallium-mold arthroplasty is indicated if fracture of the femoral head involves a third to a half of the head. If reduction has been impossible and injury to the weight-bearing surface is present, then excision of the detached fragment and primary arthroplasty seem the treatment of choice.

2. In the unusual case, when anatomical reduction is possible by closed manipulation, a good result may sometimes be expected. If practical, it might be well to confirm reduction by stereoscopic roentgenograms or posterior oblique views as described by Waller.

3. When prompt closed reduction is possible, or when the fragment of the femoral head is small and does not involve the weight-bearing portion of the hip, a good result may be achieved by removal of the fragment without redislocating the hip.

Finally, we favor Vitallium-mold arthroplasty to a prosthesis. If later reconstructive surgery should be necessary, as it was in Case 8, it can be more easily accomplished.

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Cervical-Spine Injuries in Children

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Orthopaedic surgeons are generally aware of the lateral roentgenographic appearance of the normal cervical spine in children (Fig. 1). However, a variant in the roentgenographic appearance of the upper portion of the cervical spine in some children may lead to extensive orthopaedic treatment for a supposed subluxation of the second on the third cervical vertebra. There have been few reports in the orthopaedic literature of this normal variation, which is best noted by making a lateral roentgenogram of a mildly flexed cervical spine. Roberts, in 1937, presented one of the earliest references to such cases. In his report, two patients had subluxations of the second on the third cervical vertebra following minor traumata. It was his belief that these cases bordered on the pathological. In the *Yearbook of Radiology* for 1950, an editorial comment stated that "Anterior pseudodislocation of the second cervical on the third cervical vertebra in children on flexion of the neck and absence of the usual cervical lordotic curvature in adults are additional anatomic variations in the cervical spine which may prove confusing." Holt indicated that a number of children who allegedly had traumatic dislocations of the cervical spine were examined at the University of Michigan. They had been referred for extensive treatment for this supposed dislocation of the neck. Townsend and Rowe, in 1952, reported four patients with a similar condition following an acute infection of the upper portion of the respiratory tract. Their early patients received the questionable benefit of prolonged cervical traction without an improved roentgenographic appearance of a subluxation of the second on the third cervical vertebra. As they became increasingly aware of this anatomical variant, their program of treatment diminished to a few days in a neck traction halter until acute spasm, secondary to the neck inflammation, had subsided. These cases may be similar to the cases of subluxation of the atlas on the axis reported by Berkheiser and Seidler in 1931. However, the cases reported by Townsend and Rowe had the common finding of a subluxation of the second on the third cervical vertebra. They investigated an unknown number of normal children and found that a greater subluxation occasionally existed in the normal patients than in their symptomatic patients. Bailey, in 1952, noted that infants and

FIG. 1

Normal appearance of lateral roentgenogram of the cervical spine of a six-year-old child. Note alignment of the posterior border of the vertebrae.

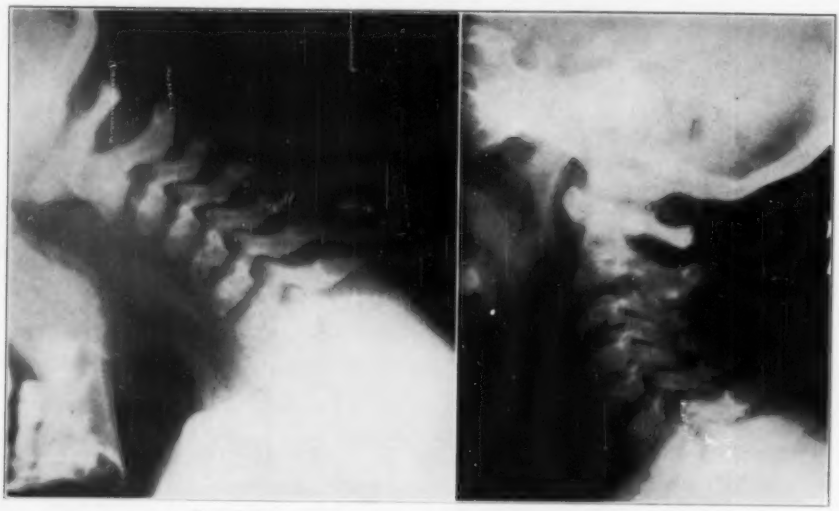

FIG. 2-A FIG. 2-B

Lateral roentgenograms of the cervical spine. Note the anterior displacement of the second on the third cervical vertebra in moderate flexion (Fig. 2-A). There is normal alignment when the spine is extended (Fig. 2-B).

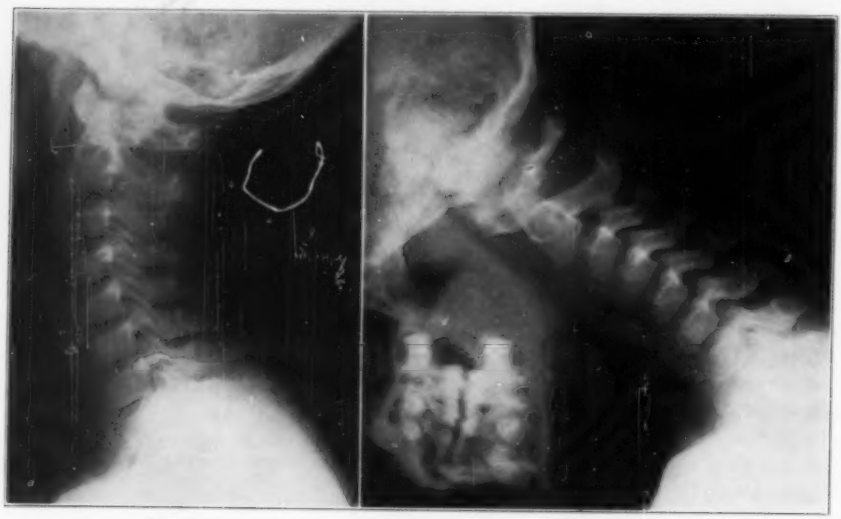

FIG. 2-C FIG. 2-D

Lateral roentgenograms of the cervical spine five years later. Note the persistence of the anterior displacement of the second on the third cervical vertebra.

children show, as a normal finding, a step-off of as much as two to three millimeters at the level of the second and third cervical vertebrae. Donaldson, in 1956, presented thirty-seven cases of acquired torticollis, with 75 per cent showing a subluxation between the second and third cervical vertebrae. However, he also described a rotatory subluxation of the first on the second cervical vertebra in some of these cases. This may well have been a pertinent pathological finding with the subluxation of the second on the third cervical vertebra a coincidental finding. Pendergrass, Schaeffer, and Hodes, in 1956, stated that

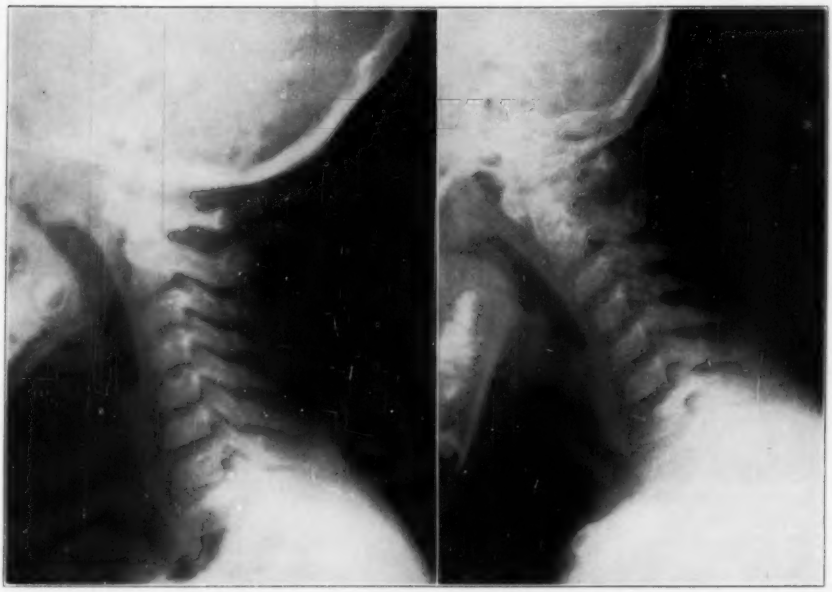

FIG. 3-A FIG. 3-B

Fig. 3-A: Lateral roentgenogram of the cervical spine in extension.
Fig. 3-B: Lateral roentgenogram of the cervical spine in flexion. Note anterior displacement of the second on the third cervical vertebra which was assumed to be pathological.

FIG. 3-C FIG. 3-D

Fig. 3-C: Persistence of displacement five months later with normal findings in neck.
Fig. 3-D: Lateral-extension view five months later.

they had seen several instances of forward displacement of the body of the second on the third cervical vertebra in children picked at random with no symptoms of illness referable to the cervical spine. They also presented several illustrations to support their statement.

The purpose of this report is to again call the attention of orthopaedic surgeons to this normal variant which may exist asymptomatically, and for which no treatment need

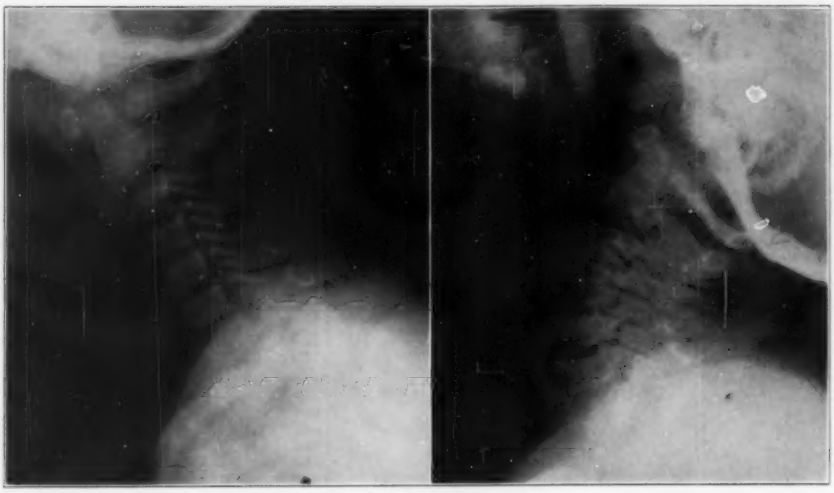

FIG. 4

FIG. 5

Fig. 4: Lateral roentgenograms of the cervical spine of a child, three and one-half years old, with no clinical evidence of neck symptoms or disability. Note the anterior displacement of the second on the third cervical vertebra when the spine is mildly flexed.

Fig. 5: Lateral roentgenogram of the cervical spine of a six-year-old child who had no neck complaints or clinical findings. Again note the relationship of the second and third cervical vertebrae.

be given when the condition is found in a child who has had only slight trauma to the neck or head. Of course, this does not mean that real dislocation or subluxation of the second on the third cervical vertebra cannot occur, but usually a child with a pathological subluxation has had a history of sufficient injury and demonstrates sufficient clinical findings to warrant such a diagnosis.

CASE 1. M. D., a child, three and one-half years old, had a history of minor injury to his neck. Roentgenograms were obtained at another hospital from which the patient had been referred for treatment of a dislocated neck. When re-examined, it was noted that the boy did not have any spasm in his neck, and had a normal range of neck motion in all directions. Roentgenograms revealed an apparent forward subluxation of the second on the third cervical vertebra (Figs. 2-A and 2-B). The child was kept under observation, but was not treated. At no time did symptoms develop. He was seen again at the age of eight and one-half. At that time the roentgenographic appearance of the cervical spine was nearly identical to the roentgenographic appearance five years before (Figs. 2-C and 2-D). The patient had been completely asymptomatic in the interval and had no limitation of neck motion at this last examination.

CASE 2. T. N., seven years old, was admitted to Chicago Wesley Memorial Hospital with a history of a rather trivial injury to his neck. He had been doing a head stand and had rolled over and landed on his back. He complained of a mild amount of neck discomfort following this incident. On examination it was felt that

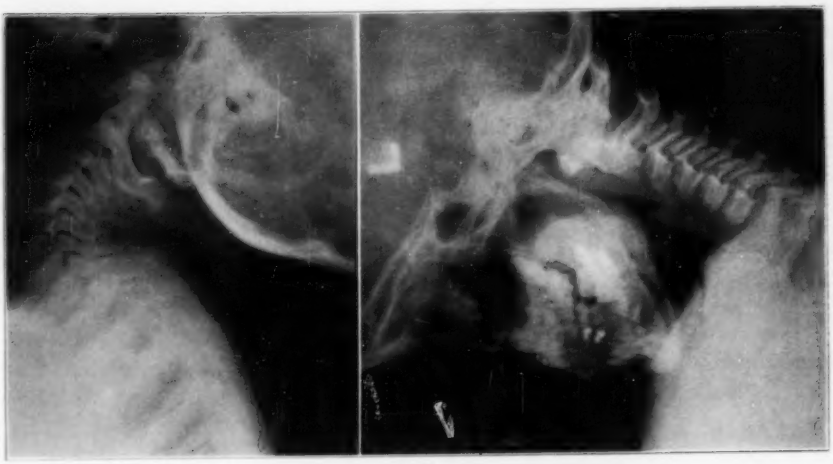

FIG. 6

Lateral roentgenogram of the cervical spine of a five-year-old child who had an injured left arm. Note the relationship of the second and third cervical vertebrae.

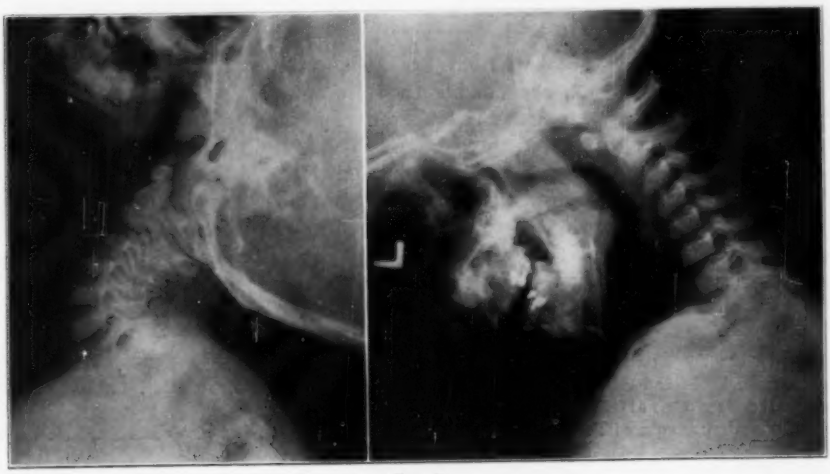

FIG. 7

Lateral roentgenogram of the cervical spine of a four-year-old child with bladder-neck obstruction. There was no evidence of neck disability. Note the relationship of the second and third cervical vertebrae.

there was some mild spasm of the neck muscles. Roentgenograms revealed an apparent subluxation of the second on the third cervical vertebra (Figs. 3-A and 3-B), and he was placed in extension cervical traction with a head halter and approximately six pounds of weight. This amount of traction was maintained for eight days, then he was placed in a plaster Minerva jacket with the head in hyperextension. At the end of two weeks, the boy was able to get in and out of the cast, so it was removed. Roentgenograms again showed the apparent subluxation on forward flexion of the spine, and he was again placed in extension cervical traction, about nine pounds of weight being used. After one week of this heavy traction, a pressure sore of the chin and moderate weakness of the anterior muscles of the neck developed. He was seen in consultation by one of the authors at this time. On examination, it was noted that the child had a normal range of motion in his neck, and no spasm of neck muscles. There were no neurological findings in either arms or legs. On reviewing the previous roentgenograms, the appearance of the second and third cervical vertebrae was felt to be a normal variant, and the traction was discontinued. He was allowed to be active, and used only a small felt collar to support the weakened neck muscles. Additional roentgenograms of the cervical spine

made about five months after the injury again revealed the subluxation of the second on the third cervical vertebra when the neck was mildly flexed (Figs. 3-C and 3-D). The child, however, was completely asymptomatic, and had a full range of neck motion in all directions.

A survey of twelve children between the ages of three and eight, at Children's Memorial Hospital, Chicago, revealed that one child, three and one-half years old, had an apparent subluxation of the second on the third cervical vertebra (Fig. 4). This child had no complaints or pathological findings referable to his neck. A similar series of thirteen children between the ages of two and ten at the Cook County Children's Hospital was also surveyed. Roentgenograms of the cervical spine disclosed that two children had marked anterior dislocation of the second on the third cervical vertebra (Fig. 5), that two children had borderline dislocations, and that the remaining nine children had normal cervical spines.

Twenty-two children between the ages of two and nine who were admitted to the Primary Children's Hospital in Salt Lake City for various conditions other than trauma to the neck, had roentgenograms made of the cervical spine. One five-year-old child, admitted for an injury to the left arm, showed a borderline subluxation of the second on the third cervical vertebra (Fig. 6). Two four-year-old children, with a clinical diagnosis of bladder-neck obstruction and congenital club-foot, respectively, showed pronounced anterior subluxation of the second on the third cervical vertebra (Fig. 7). All three of these children were free of any neck symptoms or clinical findings of neck limitation.

SUMMARY

Some children up to the age of nine years, who are normal otherwise, may show a partial anterior subluxation of the second on the third cervical vertebra. This is considered a normal variant in the appearance of lateral roentgenograms of the flexed cervical spine. A survey of forty-seven children in three different children's hospitals, all without symptoms or clinical evidence of neck disability, revealed that five children had marked subluxation of the second on the third cervical vertebra, and that three had borderline dislocations. Children who have these normal variations should not be subjected to extensive orthopaedic treatment, unless there has been a history of sufficient injury to the neck and clinical examination bears out the probability that these are pathological subluxations.

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Electron Microscopy of the Primary Spongiosa of the Metaphysis at the Distal End of the Femur in the Newborn Infant*

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The bone described in this paper is that which forms over a supporting skeleton of calcified cartilage within a zone about 1.5 millimeters broad immediately proximal to the epiphyseal line. It must be emphasized that our observations relate to this particular site, although, in the absence of references to the fine structure of the metaphyses of other bones, we have made comparison between our observations here and those derived from the study of other sites by similar methods of electron microscopy.

Bone tissue in this metaphysis as it is elsewhere is composed of cement substance and bundles of collagen fibrils impregnated with mineral. Sometimes this impregnation may be incomplete, and a layer of uncalcified matrix (physiological osteoid) may lie between the calcified matrix and the layer of osteoblasts responsible for matrix formation. Osteocytes can be found in lacunae within the calcified matrix and their processes extend into canaliculi. The ultramicroscopic details of these structures are to be described in this paper.

MATERIALS AND METHODS

The sections were cut from a zone of metaphyseal bone 1.5 millimeters wide which lay just proximal to the calcified cartilage of the epiphysis at the distal end of the femur in newborn infants. The methods used to prepare and to examine the tissue have been described previously [5].

While we believe that the fine structure of bone and cartilage matrix is relatively stable, there is evidence that postmortem changes not revealed by the light microscope can be found in the cells a very short time after death [8]. As all of this human material was obtained some hours after death, we cannot describe the finer internal structure of osteoblasts and osteocytes. However, since these cells have a gross appearance different from that of cells resembling osteoclasts, which we have seen at sites of bone absorption, some mention of the more gross structure of these cells has been made.

OBSERVATIONS

The Cells

Osteoclasts are readily identified (Fig. 1) because of their likeness to osteoblasts seen with the light microscope at sites of new-bone formation. However, there does not appear to be a great number of mitochondria, and there is little vacuolation. The endoplasmic reticulum is clearly visible.

An osteocyte in its lacuna is shown in Figure 1, and an osteocyte with processes in its canaliculi is shown in Figure 2. There is no suggestion in our electron micrographs that the canaliculus is a structure with a membranous wall, although the collagen fibrils of the surrounding matrix do arch about and crisscross on either side of a canaliculus [7]. Figure 3

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shows the beginning of the matricial enclosure of such a cell process. In some instances the osteocyte is surrounded by a narrow zone of uncalcified matrix.

The Extracellular Matrix

Osteoid: The osteoblasts at a surface where new bone is being formed are separated

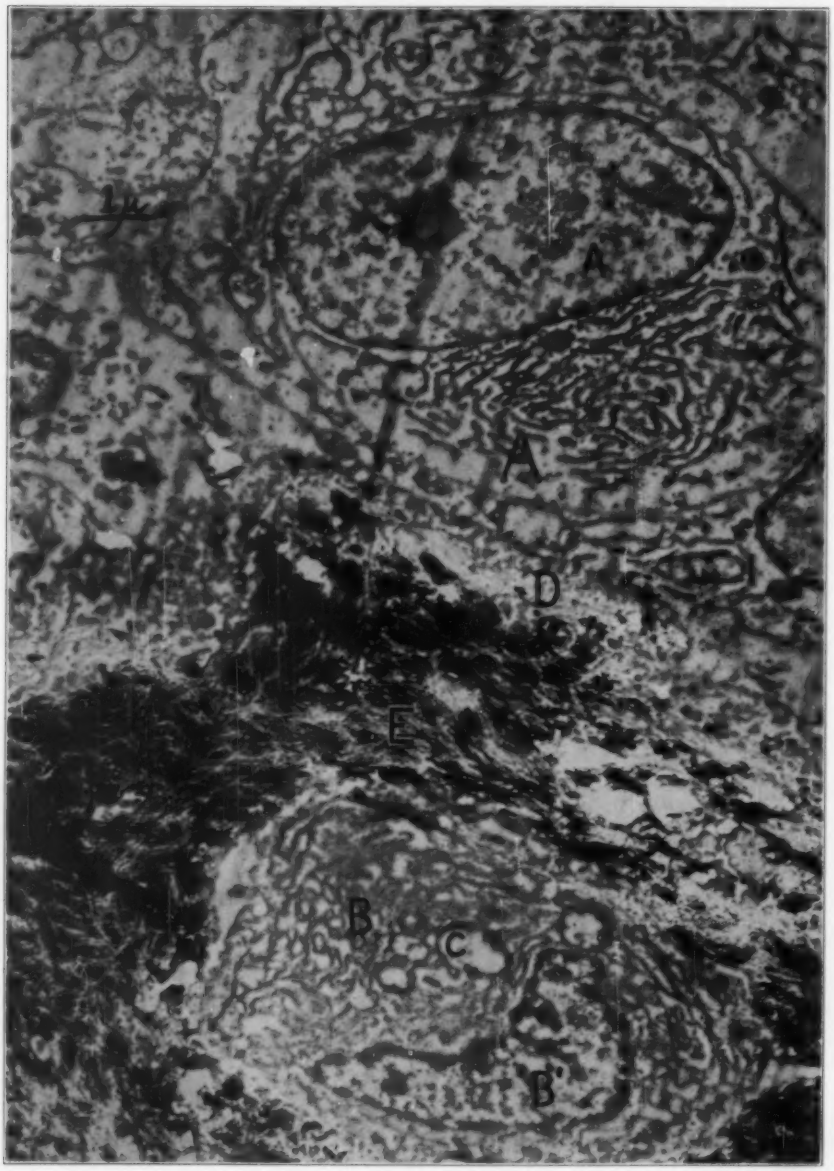

FIG. 1

Osteoblast *A* and osteocyte *B* at site of new-bone formation: *A'*, nucleus of osteoblast *A*; *B'*, nucleus of osteocyte *B*; *C*, degenerated mitochondrion [5]; *D*, uncalcified osteoid; *E*, calcified osteoid (× 12,000).

from calcified matrix by a layer of uncalcified tissue which varies from 500 Angstrom units to 2.0 micra in width. The narrowest layer observed is shown in Figure 4, and a much wider layer is shown in Figure 5. The uncalcified tissue or osteoid is composed of fibrils set in an amorphous ground substance or cement substance of low density. Most of the fibrils are about 400 to 600 Angstrom units in diameter, and they have the periodicity characteristic of young collagen [7]. The fibrils in this uncalcified osteoid sometimes form a disorderly network, but they may also be arranged in an orderly fashion and lie parallel. Figure 6 shows a loose network with fibrils widely spaced and running through the section in many directions. In Figure 5 there appears to be more orientation and the fibrils are closer together; but still some run obliquely and some run at right angles to those in the

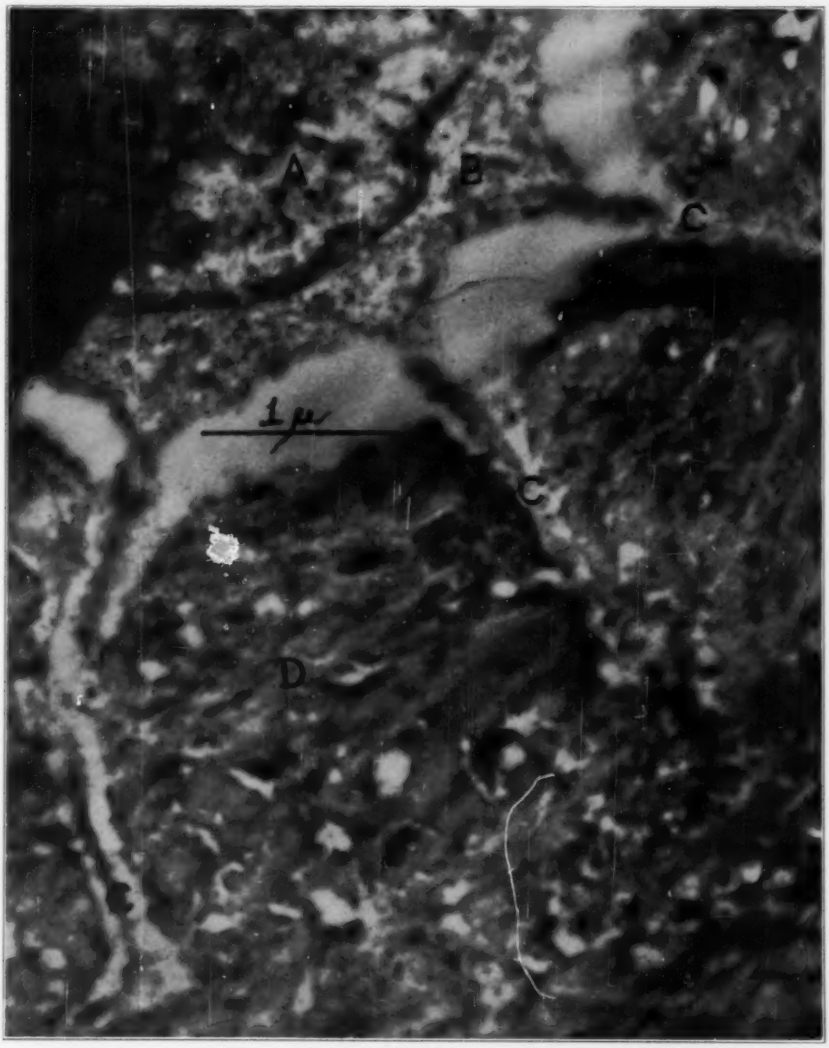

FIG. 2

Part of an osteocyte with its processes lying in canaliculi: *A*, nucleus; *B*, cytoplasm; *C*, cytoplasmic extensions in canaliculi; *D*, decalcified collagen bone matrix—here the collagen fibrils are poorly resolved.

plane of the section. The fibrils are well oriented in the osteoid in Figure 7, and seem to be "peeling off" the cell membrane. There is no suggestion of a continuation of the fibrils within the cytoplasm. Many of those adjacent to the cell are about 500 Angstrom units in thickness as those in Figures 5 and 6, but there are a few narrower ones. Periodicity is best seen in the larger fibrils.

Initiation of calcification: Throughout this zone of newly formed bone matrix the deposition of crystals or calcification follows the sequence which has been described in an earlier paper [5]. A short distance from the cell, calcification begins throughout the osteoid —the calcification front.

Calcified bone matrix: Two fairly distinct stages of organization of both crystals and fibrils can be seen once calcification of the osteoid has commenced. In the first, the majority of the fibrils tend to be haphazardly arranged, but the crystals lie with their long axes

FIG. 3

The beginning of the enclosure of an extension *A* from an osteoblast *B* in osteoid *C*. *D* is calcified osteoid (× 80,000).

parallel to the fibrils as in Figure 8. The development of this calcification front stage is confined to a relatively narrow zone between the almost fully calcified and the completely uncalcified matrix. In normal bone it is much narrower than the calcification front in epiphyseal cartilage [5]. In Figure 7, the fibrils running in the plane of section are quite clearly outlined and are almost free of crystals for a short distance (that is, osteoid zone) after which they are almost completely obscured by bone crystals.

Figure 9 illustrates the second stage of organization in calcified osteoid. Here the majority of the fibrils run close together in parallel fashion and their bands are in phase [6]. The crystals follow the direction of the fibrils and are also grouped in rows lying over the major (a-c) collagen periods. This appearance is not constantly found in all bone when the second stage is reached, since an arciform or woven arrangement of fibrils persists in some mature bone regions [1]. Also since sections are not always cut parallel with a group of

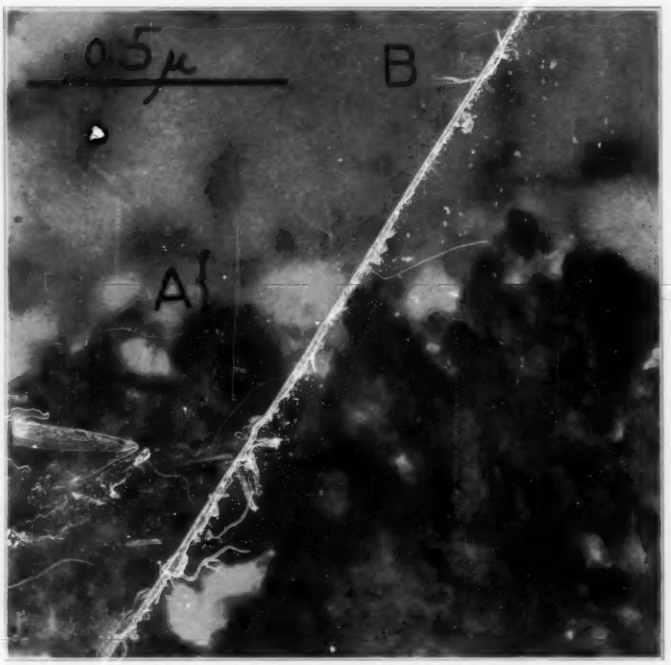

FIG. 4

A narrow osteoid seam *A* between an osteoblast *B* and calcified osteoid *C* (×80,000).

fibrils, the characteristic arrangement of mature bone seen in Figure 7 is not always obvious; for instance, when the section is cut perpendicular to the fibrils the appearance is as shown in Figure 4.

DISCUSSION

Osteoid is the organic matrix formed by the osteoblast. It always appears prior to calcification. It is observed in most of the material examined here even if only as a very narrow band at the site of bone formation as seen in Figure 4. It appears that physiological osteoid does exist even though it is not generally visible in the light microscope. If one considers the collagen fibril alone or in combination with the ground substance or cement substance as forming a template for the deposition of crystals, it seems reasonable that the

template should be in position prior to calcification. Differences in width of the osteoid border may mean that there is a local lag in the calcification of the osteoid in some areas, as suggested by McLean, so that the narrow osteoid border existing in the specimen seen in Figure 4 originally was wider and was similar to that observed in Figure 5. It is possible that there is a layer of osteoid bordering osteocytes which may accept and give up mineral depending on the physiological needs of the animal. In other words this osteoid border between cells and calcified matrix may act one moment as a storehouse and the next moment as a source of mineral for the whole animal depending on osteocyte activity. Therefore it may normally vary in width throughout life.

The fibrils of the osteoid are usually arranged in a loose network of varying complexity, and it is hard to conceive that they have been formed in orderly layers by secretion from the cells one layer at a time. They more often appear to develop at random in the cement substance. On the other hand, fibrils prior to calcification are occasionally found as shown in Figure 7 where they are more obviously layered. In Figure 7 they seem to be

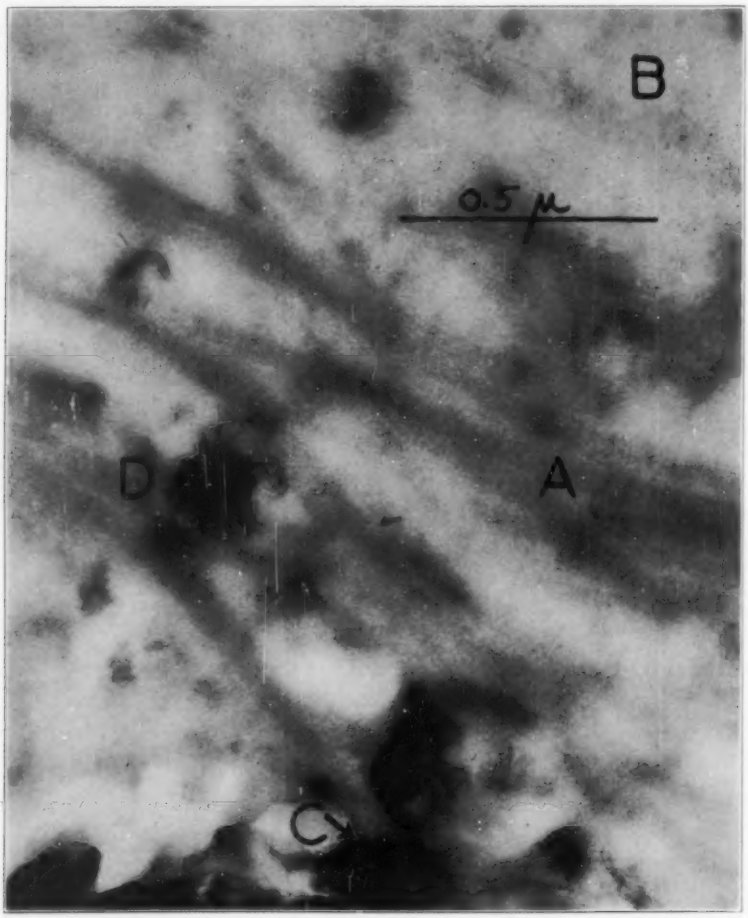

FIG. 5

Osteoid *A* separating osteoblast *B* and calcified osteoid matrix *C*. The fibrils in the osteoid, most of which run in the plane of section, are more dense and less well seen in some places as though covered by a dense cloud—a sign of beginning calcification *D* (× 80,000). (R. A. Robinson and D. A. Cameron, Clinical Orthopaedics, No. 9, p. 24, 1957.)

peeling from the cell membrane, although there is no suggestion of their continuing within the cells. If they are preformed within the cytoplasm in this site in a way similar to that described for avian tendon collagen fibrils by Jackson [2], the intracellular material must be far more subject to postmortem degeneration than are the formed extracellular fibrils for we were not able to follow these fibrils through the cell membrane.

When first visible, the crystals are associated with the fibrils of the matrix and many have their long axis parallel with the long axis of the fibrils (Figs. 7 and 8). When the fibrils are cut perpendicular to their long axis, lumps of haphazardly positioned crystals are seen (Fig. 5). This follows from the fact that only the c axis of bone crystals and the long fibril axis of collagen are parallel. The changes of haphazardly positioned crystals represent crystals in fibrils or about fibrils which are cut perpendicular to their long axis [7] (Fig. 6).

We have not seen any real evidence that the crystals in the early stage of osteoid calcification are concentrated on the major band regions (a-c region) of the fibrils as they appear to be in the more mature bone [6] (Fig. 9). The earliest calcification of bone matrix in the chick embryo is reported by Jackson and Randall. They have demonstrated crystals

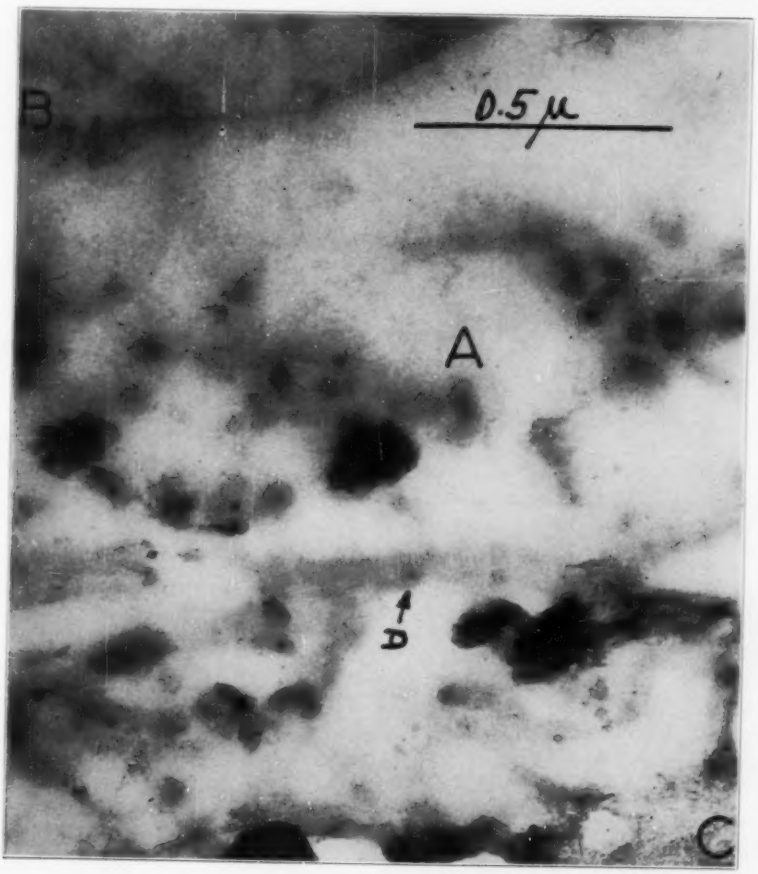

FIG. 6

Osteoid *A* between osteoblast *B* and calcified matrix *C*. The fibrils in the osteoid are more widely spaced and more irregularly arranged than those in Fig. 5 and are becoming calcified. The minor bands are observed in some places and in such places the a, b, c, d, and e bands may all have an emphasis of their density by early calcification foci (× 80,000).

less than 100 Angstrom units in length which are predominantly seen in the d to a-b region of the collagen fibrils in their material. In their published electron micrograph, crystals can be found over a wide area of osteoid and they consider that the larger crystals such as are seen in Figure 5 represent a later stage in calcification. We cannot disagree with this. In the electron micrograph which they published, the crystals of apatite apparently lie between the d to a-b regions of the fibrils in most instances, but occasionally an inorganic density appears to lie adjacent to some other regions of the fibrils. Robinson and Watson [7] concluded on the basis of their observations of the calcification front in bone and dentine matrices that the process of earliest crystal formation was normally very sudden and that

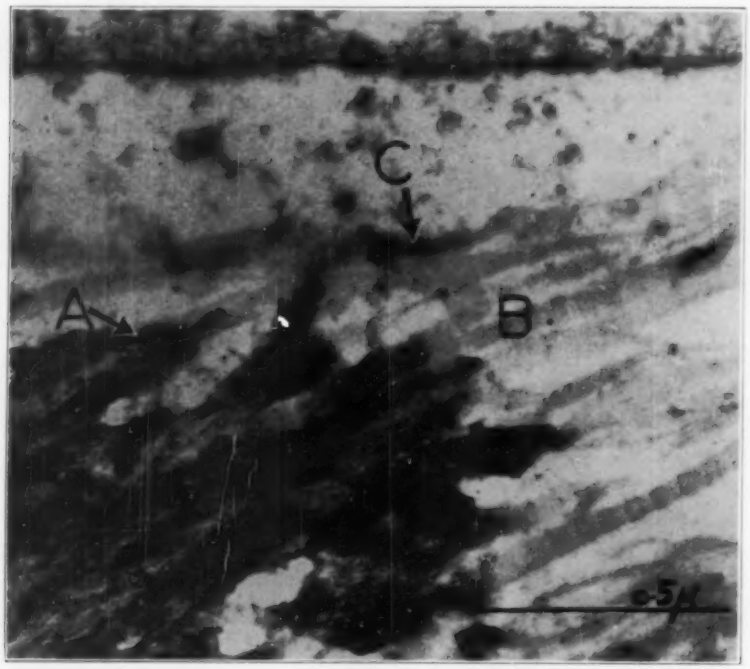

FIG. 7

Osteoid *B* and calcified matrix *A* lying close to the border of an osteoblast *C* (× 80,000).

the first crystallites might appear at any of the five (or more) minor bands (a, b, c, d, and e) in each major collagen period. It may be true that the space between the d and a-b bands (that is the region of the e band) is the first region associated with calcification. In view of the increasing knowledge of collagen chemistry, this more specific localization of earliest calcification by Jackson and Randall may be of great importance in determining a distinct chemical unit associated with collagen fibrils of calcified matrices in the region of the e band which is involved in the inception of the calcification process.

It therefore appears to the authors that osteoid when first organized by an osteoblast is not calcified; then this osteoid suddenly becomes calcified if normal. In this region of primary calcification, the fibrils tend to be irregularly arranged, and although the crystals that form in relation to them have their long axis parallel to the long axis of the fibrils, they are not grouped along the fibril at 630 Angstrom intervals.

In the third stage of osteoid development (or the second stage of calcification) the tissue takes on the appearance characteristic of mature bone [6] in which the fibrils are packed in parallel array. Their major band areas are then in register and crystals are concentrated at these bands.

The difference observed in the two zones of calcified osteoid beneath the uncalcified osteoid could possibly be the result of different cycles of activity on the part of the osteoblast. At one time the osteoid fibrils could be formed in a loose network; at another time they could be formed more compactly and in a parallel arrangement. In some regions even in compact normal human bone, the fibrils running between regions of parallel fibrils lie in an arciform arrangement [1]. However, it is much easier to find groups of parallel fibrils in the less recently calcified osteoid than it is to find them in the uncalcified osteoid. It appears likely to the authors that there has been, shortly after the initial calcification of the osteoid, some spatial reorganization of both fibrils and crystals.

Figure 9 further substantiates previous statements about the basic pattern of the crystals in more mature bone. The periodic structure of the underlying collagen fibrils is made clear throughout the picture by the rows of crystals lying across the more or less parallel aligned fibrils. In isolated parts of the section, small crystals can be seen lying on the major (a-c) band regions of the underlying fibrils [5].

The position of crystals in relation to the cross section of a fibril is not certain. Some

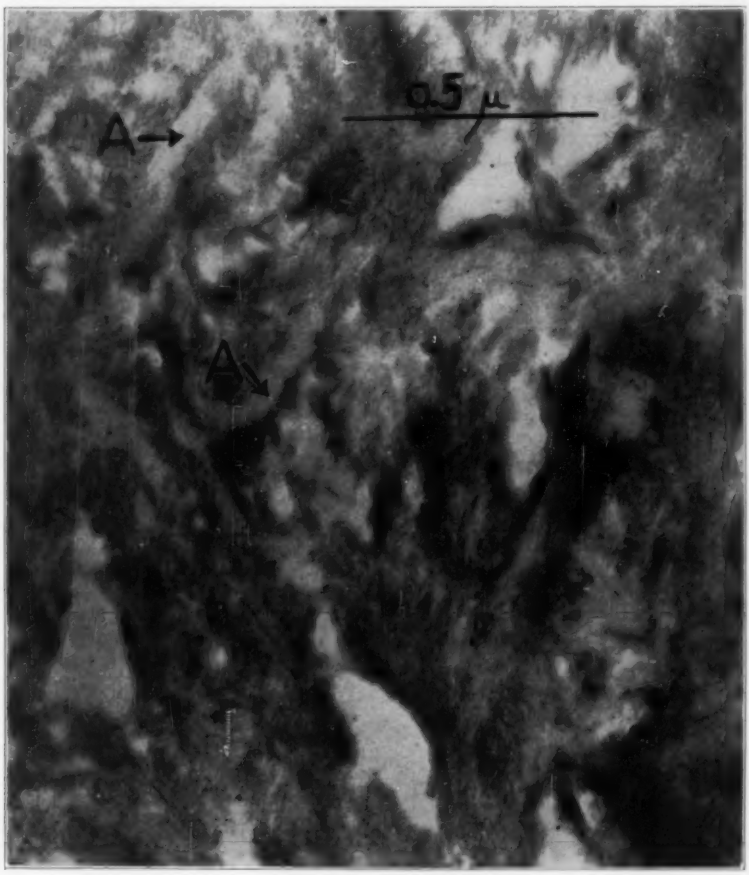

FIG. 8

Early calcification of the matrix. The crystals are parallel with the fibrils but are not arranged so that the collagen periodicity is emphasized as it is in Fig. 9. In some areas (*A*) the crystals appear to be at the margin of the fibrils while the center is free of mineral (× 80,000).

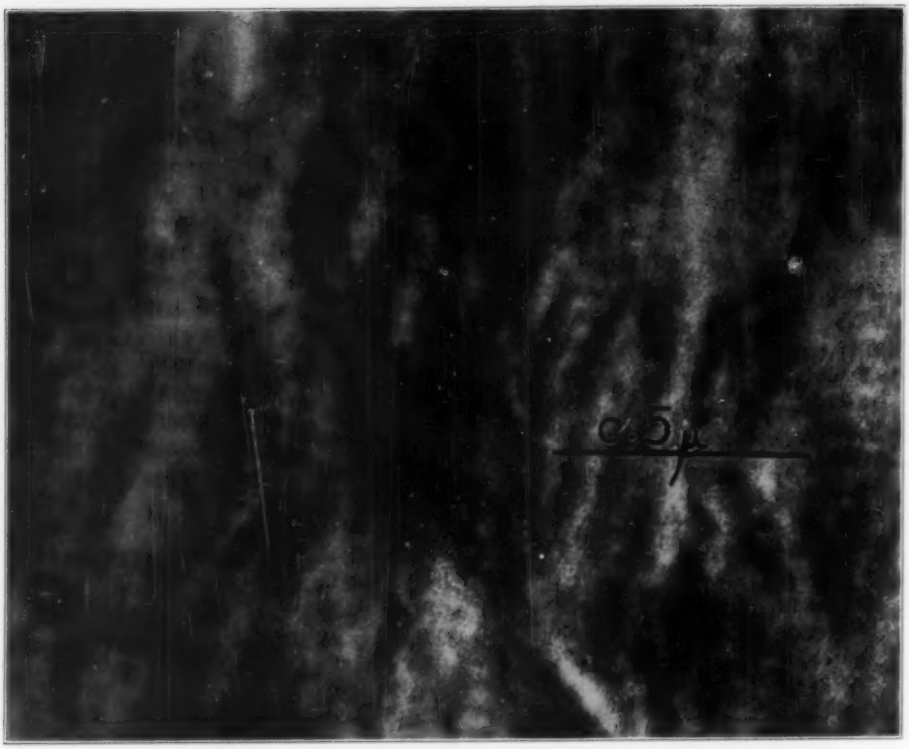

FIG. 9

The crystals lie on the fibrils and emphasize the collagen periodicity. The fibril direction is perpendicular to the magnification index line (× 80,000).

of the inorganic material may be within the fibrils [7] but this is probably not always true, at least in the zone of primary osteoid calcification, for in Figure 8, areas can be found where fibrils running in the plane of section are not overshadowed by crystals. At least in the section of bone in Figure 8 the crystals only lie on the surface of fibrils and between fibrils marked *A*.

SUMMARY

The extracellular osteoid matrix of the spongiosa of the metaphysis at the distal end of the femur in newborn infants can be divided into three zones.

The first is uncalcified osteoid composed of a network of collagen fibrils set in ground or cement substance. This has been seen in some degree between the osteoblasts and calcified osteoid in all sites in the material examined. The width of this uncalcified zone varies but is usually too narrow to be resolved by the light microscope.

The matrix becomes calcified and so forms the second zone. The dividing line between the calcified and uncalcified osteoid matrix is fairly clear-cut. The crystals are deposited with their long axes parallel with the long axes of the fibrils and probably lie mostly outside the fibrils and are not concentrated at 630-Angstrom intervals along the fibrils. At this stage the fibrils still tend to form an intertwining network.

In the third zone, fibrils are more generally grouped in a parallel fashion, and their periodic band areas are in phase. The crystals lie with their long axes parallel with the axes of the fibrils and are concentrated in rows at about 630 Angstrom-unit intervals along the fibrils. The rows of crystals are in register with the periodic bands of the fibrils.

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DISCUSSION

Analysis of Methods of Fusion for Scoliosis

(Continued from page 646)

We wish Dr. Moe had included not only technique of fusion in securing better results, but also other variables including:

1. Type of body cast. We feel it is important whether it be a cast with headpiece, shoulder straps, or only as high as the arm pits. Loss of correction is one of the best signs of pseudarthrosis and it is less likely while the fusion is solidifying through the use of a well applied adequate cast.
2. Period of immobilization. No mention is made of time.
3. Time of ambulation. Early ambulation without significant loss is possible with an adequate cast.
4. The severity of the scoliosis. The severely curved spine with good correction requires a stronger fusion than a mildly curved spine or one in which there is little correction.
5. The patient's metabolism. The least considered variable is that of the patient's metabolism which may account for some of the pseudarthroses in spite of excellent technique, adequate immobilization, and other correct methods.

A meticulous subperiosteal dissection and articular-facet fusion of Hibbs without additional bone has been done for the past thirty years. More and more have we realized the importance of good articular-facet fusion. It is important not only to remove the articular-facet cartilage, but also to make the surfaces incongruous. This is done by an interlocking articular-facet fusion.

Dr. Moe (closing): In answer to Dr. Risser's questions regarding the type of cast, during the past several years we have used the localizer cast as described by Risser. I do not let the patients up at once because sufficient correction has been lost in this way to cause me to feel that it is not worth while. Each patient is in this localizer cast for a minimum of eight months and is up after about six months. The patient is then put into a short cast if the scoliosis is low on the spine. If it is a high curve the long cast will be maintained until perhaps eleven months on the average, often over twelve months. The criterion for that, of course, is the appearance of the graft on the roentgenogram.

The time of ambulation I have mentioned. The patients are up at six months on the average, sometimes much earlier. The greater the correction, the earlier is ambulation. Of course a patient with a fully corrected spine, or nearly so, can be allowed up quicker than one in whom the scoliosis is more severe. Time did not permit mentioning the severity of the curve which I hope will be covered in the final paper to be published. However, in most of the patients whom we see the curves are as great as 60, 70, and 90 degrees. We do not see many patients in whom the deformity is at the early stage of development. Many of these we do treat conservatively for a period of time until we can see what is happening to them.

Evaluation of the metabolism of the patients has not been possible due to lack of laboratory facilities.

Recent Observations on Bone Structure

BY BENGT ENGFELDT, M.D., UPPSALA, SWEDEN

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Bone is a highly specialized mesodermal derivative which consists of specific cell types and intercellular substances, and which attains its characteristic hardness by the acquisition and maintenance of mineral salts.

The cellular elements in bone tissue have distinctive but probably overlapping functions. The osteoblasts take part in the formation of bone, the osteocytes probably function in maintaining the structural and metabolic integrity of fully formed bone, while the osteoclasts are associated with the resorption of bone. The organic part of the intercellular substance is to a great extent built up by the fibrillar protein, collagen. In addition to the fibrous component, small amounts of non-protein material have been demonstrated to be present, among which is chondroitin sulphate. The inorganic fraction consists of a substituted hydroxyapatite.

Bone tissue is formed during embryonic life through the differentiation of immature mesenchymal cells to osteoblasts. The formation of bone may proceed in two different ways. Either a cartilaginous model is formed which is subsequently replaced by bone tissue, or alternatively, bone tissue appears directly through transformation from the mesenchyma. The latter process, termed membranous ossification, occurs in all adult bones of the body, and it is this mechanism which in later life is responsible for the internal reconstruction of bone. Growth of bone associated with a cartilaginous model, or endochondral bone formation, is exemplified after birth by the cartilaginous epiphyseal growth zones of all long bones, where longitudinal growth occurs.

The literature dealing with the structure, chemical composition, and physiological properties of bone tissue is extensive. Careful investigations of the structure of bone tissue have been performed with ordinary histological methods. Hence, it is not my intention to give here a survey of our present knowledge in this field; but instead to indicate some of the newer observations on the structure of bone tissue made by our research group.

The recent great advances in the field of biophysics have permitted the development of new methods for the study of bone. The results of these methods have considerably extended our knowledge of and interest in this tissue. The investigations of bone here discussed are those which we have made by employing different biophysical techniques, including microradiography, microinterferometry, and autoradiography. In addition, routine histological and histochemical methods supplemented these biophysical techniques. The ultrastructure of bone tissue has been studied by means of x-ray diffraction methods. A survey of the results obtained in this field is to be found in the work of Carlström [3, 4].

The inorganic fraction of bone tissue has been studied by means of microradiography performed on thinly ground sections [25]. The absorption of x-ray in the wave length range of one to three Angström units by bone tissue is from a practical standpoint solely dependent on the presence of bone salts [14]. Thus, microradiograms obtained by this radiation indicate both the amount and distribution of bone salt in the section. Considerably softer x-rays, in the wave length range of eight to twelve Angström units have also been used in microradiographic studies of the organic part of bone. These investigations were performed on decalcified sections. This type of soft microradiography permits the determination of the distribution of dry mass in the organic subtance [28]. The evaluation of the

microradiograms can be performed visually or by quantitative densitometric measurements.

The optimal conditions for visual evaluation of microradiograms were considered in

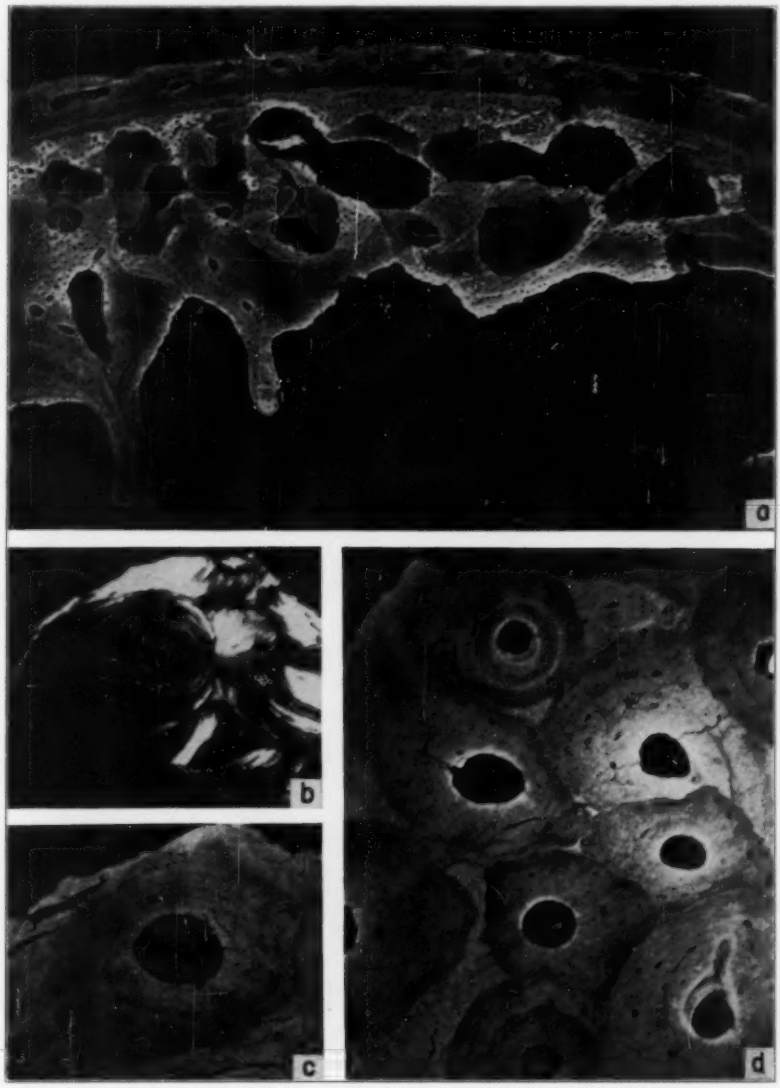


FIG. 1

Fig. 1, *a*: Microradiogram (× 60) of a ground transverse section 100 micra thick from a normal rib of a child, showing the distribution of mineral salts. Light areas have a high x-ray absorption and thus a high content of mineral salts. Many resorption cavities as well as newly formed areas with a low content of mineral salts are seen.

Fig. 1, *b*: A part of the same section as in Fig. 1, *a* decalcified, is shown in photomicrograph (× 136) made in polarized light. The arrangement of the collagen fibers is seen.

Fig. 1, *c*: Microradiogram (× 190) of a ground section five micra thick showing an indication of a lamellar structure of an osteon.

Fig. 1, *d*: Microradiogram (× 167) of a ground transverse section, twenty micra thick, from normal compact bone of an adult, showing Haversian systems with different content of mineral salt. The osteocytes have no absorption and thus show up as dark spots.

a paper by Henke and associates. If the microradiogram density is kept at a fixed value, the contrast will increase with the absorption index. Differences in density which are visually detectable under optimal conditions are less than 1 per cent. In bone samples examined under standard conditions, differences in absorption index of about 1 per cent are visually detectable[30].

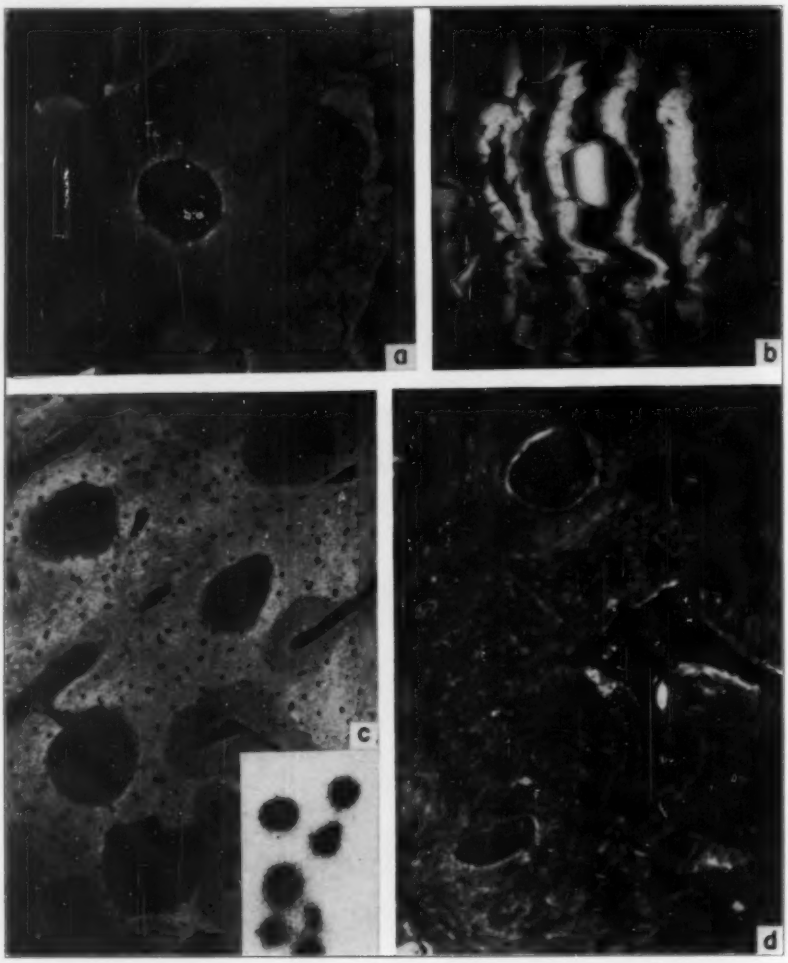


FIG. 2

Fig. 2, *a*: Microradiogram (× 245) of a ground transverse section, twenty micra thick, from compact bone of an adult showing a rather young osteon with a decreasing concentration of mineral salts from the canal toward the periphery of the system.

Fig. 2, *b*: Microinterferometric photograph (× 243) of the same undecalcified osteon as shown in Fig. 2, *a*. The background bands, crossing the field, can be seen at the upper left and in the Haversian canal. The interference bands in the specimen are shifted because of differences in dry mass per unit area and from this photomicrograph it is evident that the mass in the osteon is increasing from the periphery toward the Haversian canal.

Fig. 2, *c*: Microradiogram (× 113) of a ground transverse section, 100 micra thick, from compact bone of a dog injected with Sr^{89} a few days before it was sacrificed. At the lower right the corresponding autoradiogram is inserted. Osteons with a low content of mineral salts, corresponding to newly formed areas show a high uptake of the isotope.

Fig. 2, *d*: Soft microradiogram (× 127) of decalcified section, ten micra thick, from compact bone of a newborn baby without skeletal disease. The organic part of the bone tissue shows an even distribution of dry mass.

Variations in the absorption index for a bone sample are mainly caused by changes in the absorption index for the inorganic fraction. The mass absorption coefficient of the bone mineral will vary only slightly as the composition of the bone salt can be considered relatively constant. By determining the linear absorption coefficient, μ, a value is obtained which will be approximately proportional to the amount of bone mineral per unit area. Variations of μ will be approximately equivalent to the mass variations of the mineral salts in the bone sample. The errors associated with this technique will include those arising from thickness determination and the photographic-photometric procedure, and also from biological variations in the specimen. It has been shown by Wallgren and Holmstrand that the sensitivity of the method in determining mass differences was about 1 per cent at an average specimen thickness of 100 micra. In a model experiment in which a sheet of fused quartz was used as a test object, the standard error in determining the linear absorption coefficient for quartz was shown to be 1.6 per cent when the thickness was measured on easily defined structures.

Along with the microradiographic studies of the organic and inorganic parts of bone, microinterferometric measurements have also been performed on the same material. The microinterferometric technique permits the determination of the amount of dry mass per unit area in the tissue section. The theory of dry mass determinations by means of interference microscopy has been presented by Davies and Wilkins and by Barer. In principle the dry mass per unit area, M, can be calculated from the following formula $M = \frac{\phi}{\chi}$, where ϕ is the optical path difference produced by the object, and χ is 100 α where α is the specific refractive increment which for most substances occurring in biological concentrations is approximately constant. By measuring the specimen in media of different refractive indices, for instance water and paraffin, both dry mass per unit area and specimen thickness can be estimated. For a specimen immersed in water an optical path difference of one wave length corresponds to a dry mass of $[3\mu\mu g/\mu^2]$. Path differences of one-tenth of a wave length can easily be detected by visual estimation. By photometric methods fractions down to 1/300 of a wave length can be measured.

When microinterferometric methods are applied on bone tissue, the dry mass per unit area can be determined both for the organic and inorganic fraction. Measurements are first performed on ground undecalcified section. The values thus obtained represent the composite dry mass per unit area of the organic and inorganic constituents of the tissue. After removal of the mineral salts the organic fraction can be measured, and by subtraction the value for the inorganic fraction may be obtained. Results obtained from x-ray techniques and microinterferometry on bone structures have been compared and good agreement found [6].

Thus, we have two independent methods by means of which it is possible to determine separately the amounts of organic and inorganic material in bone. Investigations of this type have also been combined with autoradiographic studies of the uptake and distribution in bone of a series of different radioisotopes.

Microradiographic and microinterferometric investigations on compact bone tissue have shown that there is an uneven distribution of mineral salts. The outer and inner circumferential lamellae and the interstitial lamellae are, in general, evenly and highly mineralized, while the osteons (Haversian systems) exhibit a varying degree of mineralization. Newly formed, young osteons have a low mineral content which increases with advancing age. In a single osteon there are also variations in bone-salt concentration in different areas. In the young osteon the concentration is highest close to the central canal, but decreases towards the periphery of the system. This fall in mineral content is less pronounced as the system grows older, and in the very old, highly mineralized system, an even distribution of mineral salts is found. Microradiograms demonstrate that the resorption of bone tissue, which goes on throughout life, may occur simultaneously in

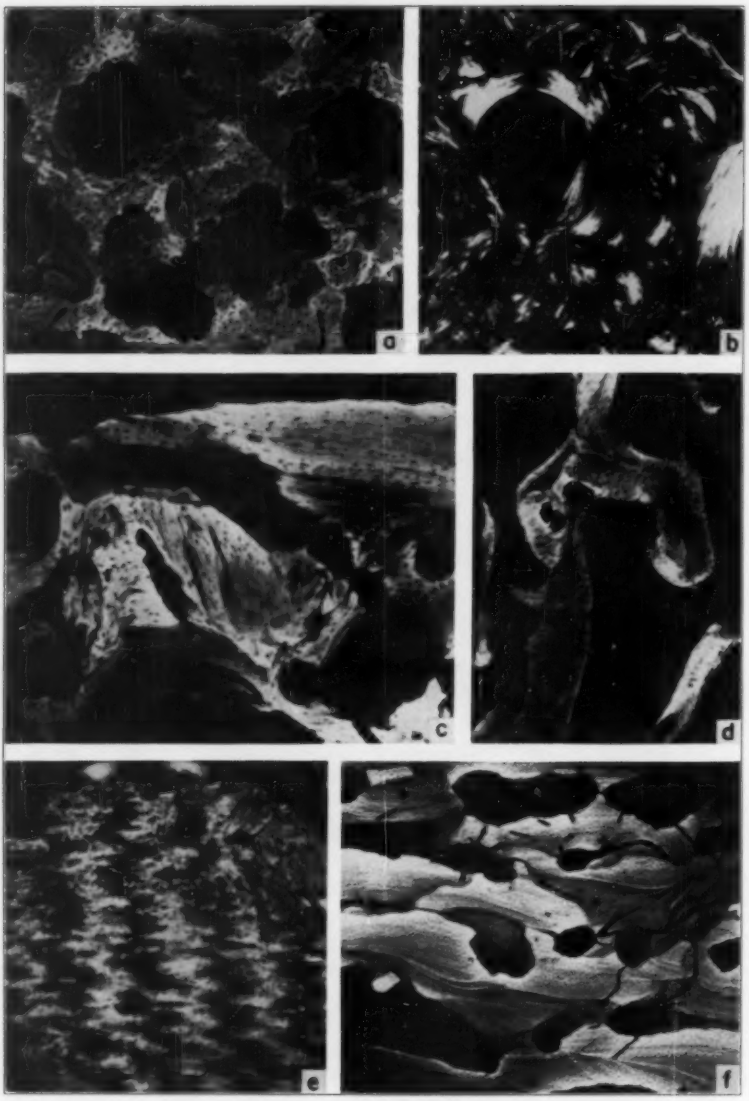


FIG. 3

Fig. 3, *a*: Microradiogram (× 65) of ground transverse section, 100 micra thick, from compact bone of a person with Paget's disease showing the great variation in mineral content in different structures. The mosaic pattern is also evident.

Fig. 3, *b*: Photomicrograph (× 65) of decalcified section of bone tissue from a person with Paget's disease made in polarized light. The irregular arrangement of the collagen fibers is demonstrated.

Fig. 3, *c*: Microradiogram (× 77) of ground transverse compact bone, 100 micra thick, from rib of a person with vitamin-D resistant rickets showing the irregular mineralization of the bone tissue.

Fig. 3, *d*: Microradiogram (× 85) of ground transverse section, 100 micra thick, of compact bone from tibia of a person with vitamin-D resistant rickets who was treated with massive doses of vitamin D. The distribution of mineral salts is still abnormal in places giving an impression of a mosaic pattern.

Fig. 3, *e*: Microinterferometric photograph (× 190) of a decalcified transverse section, ten micra thick, of bone tissue from a person with osteogenesis imperfecta. The interference bands passing the tissue produce a pronounced zigzag pattern indicating rather great variations in dry mass per unit area in different lamellae.

Fig. 3, *f*: Microradiogram (× 45) of a ground transverse section, 100 micra thick, of compact bone from femur of a person with osteogenesis imperfecta. No osteons are seen.

both newly formed areas of bone possessing a low content of mineral salts, as well as in older and highly mineralized bone.

In a study of the mineralization of fetal bone it has been demonstrated that the first phase of mineralization, up to about 70 to 80 per cent, is a very rapid process which occurs during a period of approximately three weeks[35]. The mineralization from 70 to 80 per cent up to 100 per cent is a much slower process. It seems probable that the same is true for the osteons. They become rapidly mineralized up to 70 to 80 per cent of total

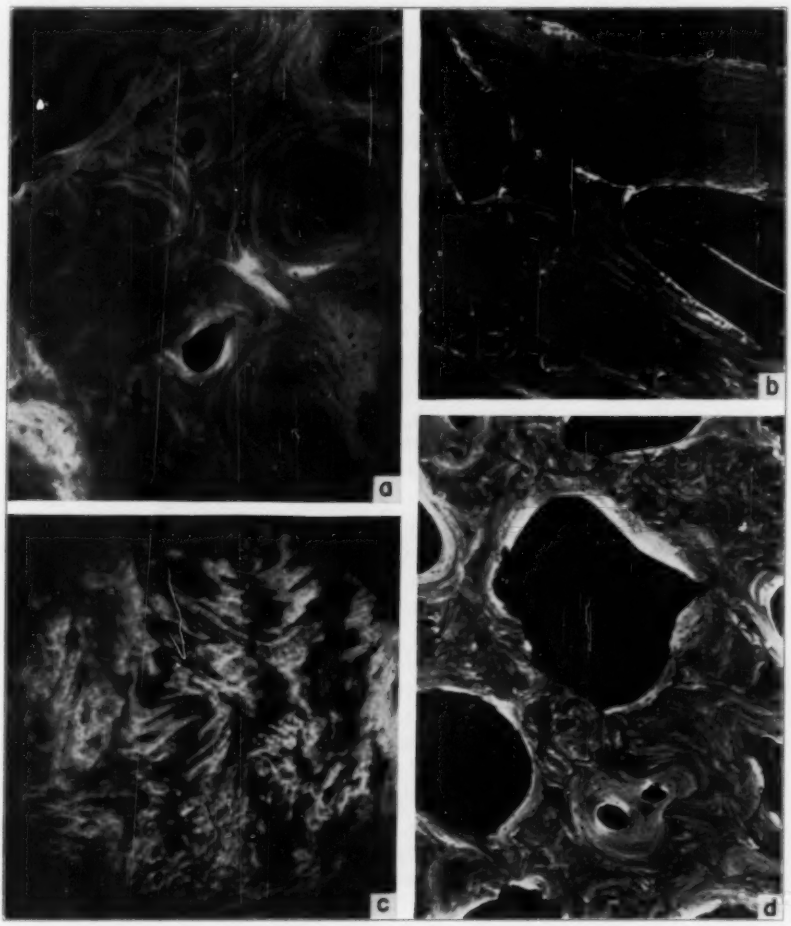


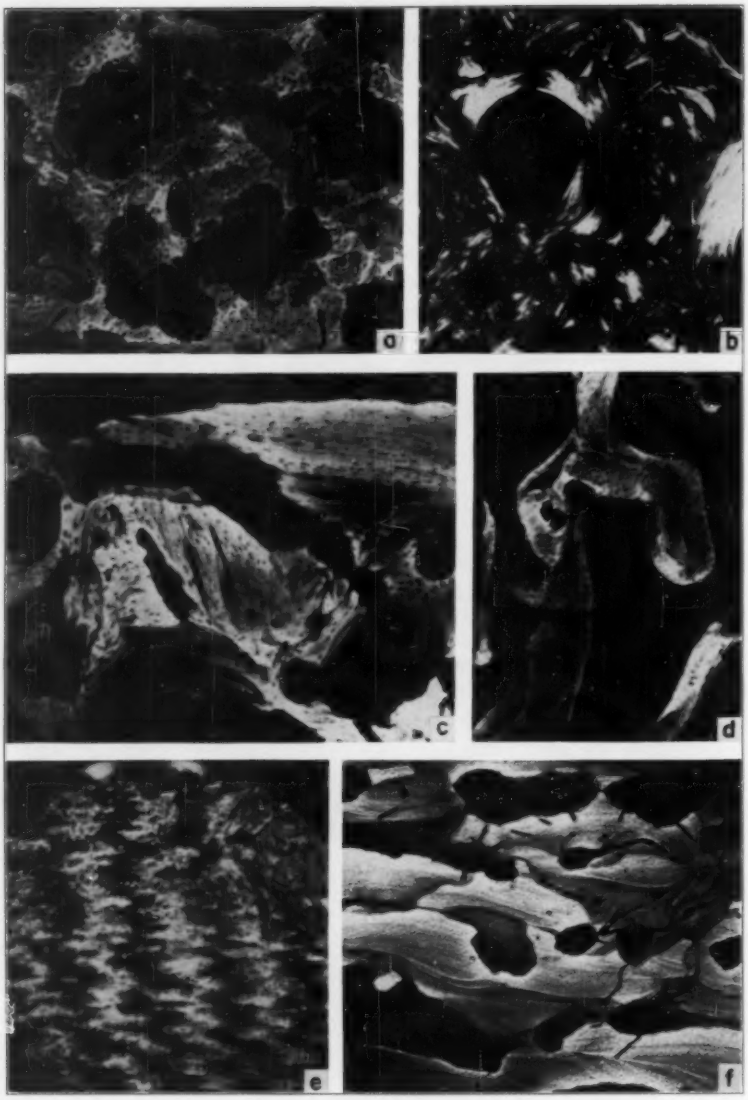
FIG. 4

Fig. 4, *a*: Soft microradiogram (× 103) of a decalcified transverse section, ten micra thick, of compact bone from a person with vitamin-D resistant rickets, showing the distribution of dry mass. A few osteons are seen and, between them, a tissue with a somewhat irregular mass distribution.

Fig. 4, *b*: Soft microradiogram (× 63) of a decalcified transverse section, ten micra thick, of bone from a person with osteogenesis imperfecta. The dry mass of the bone trabeculae can be seen arranged in thin lamellae.

Fig. 4, *c*: Microinterferometric photograph (× 205) of a decalcified transverse section, ten micra thick, of compact bone from a person with Paget's disease. The interference bands are seen to run very irregularly across the tissue, indicating great variations in dry mass in different areas.

Fig. 4, *d*: Soft microradiogram (× 68) of a decalcified transverse section, ten micra thick, of compact bone from a person with Paget's disease, showing great variations in the distribution of dry mass in the organic component of the bone tissue.



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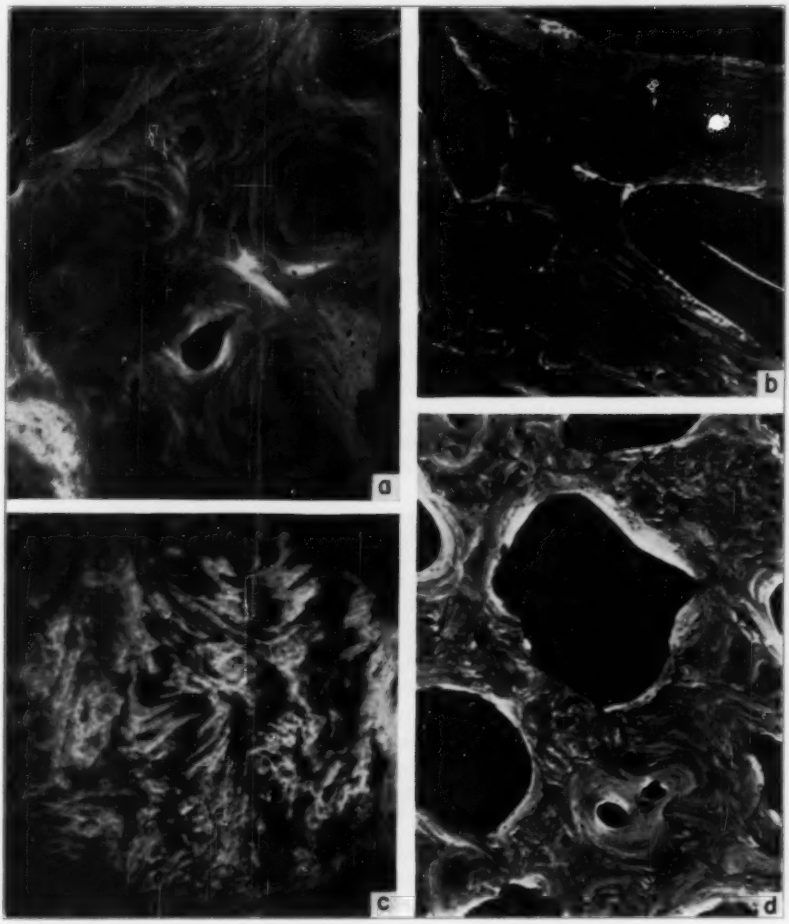

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mineralization and at that stage of development they demonstrate the characteristic decrease in mineral-salt content from the central canal toward the periphery. They then slowly reach full mineralization; at the final stage the whole osteon is evenly mineralized.

Microchemical investigations have been performed on single osteons, dissected from ground transverse bone sections fixed in alcohol. A microradiogram was made of the bone section and an enlargement of it studied to select suitable bone structures. By visual estimation of the microradiograms three groups of osteons were selected for chemical analysis, young osteons with a very low x-ray absorption, old osteons with high x-ray absorption, and an intermediate group. Small pieces of interstitial highly mineralized bone were also taken for analysis. Nitrogen and phosphorus were determined in these microscopic structures as representatives of the organic and inorganic fraction of the bone tissue, respectively. By this means a significant difference in mineralization between young and old osteons was demonstrated. The difference between these groups amounted to 22 per cent on the average.

The organic part of normal bone tissue investigated in histological sections decalcified in versene at pH 7 generally showed an even distribution of dry mass when different structures were compared (structures of the second order [22]). This finding is in contrast to the uneven distribution of the mineral salts. However, careful examination of very thinly ground sections (five to ten micra) of compact bone has indicated that within individual Haversian systems, both mineral and matrix are unevenly distributed in a lamellar way. Thus, if a section cuts the osteon in a direction perpendicular to the long axis, an indication of a lamellar structure may be observed in microradiograms. Lamellae with a high mineral content alternate with lamellae with a lower degree of mineralization [26]. If such a section is then decalcified and the distribution of dry mass per unit area of the organic component of the osteon is determined, one will find the same lamellar structure which exhibits alternately high and low mass. This finding may be interpreted as representing the alternation of lamellae which are rich in collagen fibers, thus possessing a high mass, with lamellae which are poor in collagen fibers. The question whether the lamellae in which a low content of collagen has been demonstrated correspond to those which possess a high content of mineral salt is still controversial [23, 24].

The *in vivo* uptake of mineral-seeking radioactive isotopes in the bone tissue has been shown to occur very rapidly in zones with a low content of mineral salts, especially the newly formed areas. This behavior on the part of mineral isotopes has been shown to hold for physiological substances such as phosphorus and calcium[9]. However, a similar pattern of uptake has also been demonstrated for other elements [12], which do not normally take part in the formation of bone, for instance strontium-90, biologically one of the most important by-products of atomic fission [13].

X-ray crystallographic studies on the ultrastructure of the inorganic fraction of fetal bone have shown that the crystallites in the newly deposited areas are smaller than in fully mineralized bone and undergo rapid growth. These circumstances certainly play a role in the mechanism by which different ions are taken up in the bone tissue [27, 35].

Studies on the *in vitro* uptake of fixed bone tissue of the previously mentioned radioactive isotopes have shown a similar pattern, as for isotopes administered *in vivo*, indicating that at least a part of the uptake is of purely physical nature [10, 17].

On histochemical investigations of thinly ground sections from compact bone it has been demonstrated that there is a narrow zone next to the central canal of the growing Haversian system, corresponding to a lamella, which is periodic acid-Schiff positive. It also stains metachromatically with toluidine blue. This area has been shown in *in vivo* experiments to have a high uptake of sulphur-35 labeled sulphate which is associated with the organic component of the bone tissue. These findings indicate the presence of a sulphuric-acid containing mucopolysaccharide in the organic part of bone tissue under formation, perhaps chondroitin sulphuric acid [21].

Bone tissue from persons with Paget's disease [8, 10] osteopetrosis [15, 22] osteogenesis imperfecta [16], hypophosphatasemia [19], primary vitamin D-resistant rickets [24, 37], and other diseases [4, 11, 18, 20, 23, 31] has been studied by the use of the previously mentioned biophysical methods and found abnormal in many respects. These deviations from the normal are found both in the organic and inorganic parts of the bone tissue. Some of these findings are demonstrated in the accompanying illustrations. For further information on this subject, which is beyond the scope of this paper, the reader is referred to the original publications.

The new and partly quantitative techniques used in these investigations have allowed further insight into the structural organization of both normal and pathological bone tissue. It is hoped that these findings will stimulate further research in this field. Certainly they serve to remind us of the fact that bone is not only a supporting organ, but is also a dynamic physiological system of the body.

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Quo Vadis Orthopaedia Americana*

EDITORIAL

BY FREDERIC C. BOST, M.D., SAN FRANCISCO, CALIFORNIA

Whither goest thou, American Orthopaedics? This question is of vital importance to every Orthopaedic Surgeon. It is a question to be answered in a large part by the members of The American Academy of Orthopaedic Surgeons. As an Academy, we constitute the largest organized group of practitioners, of teachers, and of students of research presently devoting our efforts to Orthopaedic Surgery. Our opinions and our conduct of our specialty cannot fail but to exert a determining influence upon the course of Orthopaedic Surgery.

We, the members of this Academy, are among the inheritors of a major medical specialty which, from its inception, has been dedicated both to the medical care and to the continued welfare of the injured, the crippled, and the disabled. Our inheritance constitutes a well developed specialty of broad scope which has earned its position as an integral part of the total field of medicine.

As its inheritors, it is our duty to guide Orthopaedic Surgery toward a greater scientific achievement and to manage our inheritance with wisdom lest we allow it to become shrunken and dissipated. These duties will require of us a diligence in reference to the scientific aspect and to the teaching of our specialty. They also require our constant and alert attention to the progress of our inter-medical relations and to the socio-medical and the medical economic aspects of our specialty. At the present time our tasks are made difficult by the rapid progress of medical science and by the extending paternalism which is now directed toward the health and welfare of the crippled and the disabled. Possessed of a record of excellent medical progress and a long experience with both medical and social welfare, Orthopaedic Surgery should be equal to these tasks.

Wishing to preserve the intactness of our specialty and to continue the practice of medicine under the system of free enterprise, we must be prepared to meet these ever-changing developments with a course of positive action and a dynamic leadership. Reflection upon past experience should give to the members of this Academy some indication of the means by which they may intelligently direct the future course of Orthopaedic Surgery.

SCIENTIFIC ACHIEVEMENT

Of the course of their major function, scientific achievement, Orthopaedic Surgeons may be justly proud. Their contributions have provided a steady progression in the clinical field, covering the recognition, the diagnosis and classification, and the therapeusis of the disorders of the musculoskeletal system. Just as with medicine in general, the growth of our specialty has been marked by a continual dissatisfaction with empiricism, leading to an ever-increasing amount of inquiry and research. If, as some believe, basic research has lagged somewhat behind the clinical developments of our field, we can now rest assured that measures are being taken to overcome this early dereliction. Previously the training for our specialty placed an emphasis upon the art and the practice of Orthopaedic Surgery, little preparing us for the work in the field of basic research. By their present training, many of our students are as well prepared for research as are those in other branches of medicine, and we may expect great contributions from our younger

* Presidential Address read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 3, 1958.

Orthopaedic scientists. Nevertheless, let us not minimize the value of a carefully documented clinical research or become neglectful in our duty to provide the patient with an expert and a sympathetic service.

This Academy has played an important role in the scientific advancement of Orthopaedic Surgery. The excellent scientific meetings and exhibits, the audio-visual demonstrations, and our symposia indicate the broad knowledge and the varied interests of our members. The Instructional Course Program has presented an unequaled opportunity for instruction at a graduate level. The collateral or combined meetings with the American Society for Surgery of the Hand and the Orthopaedic Research Society afford an opportunity for education in special fields closely associated with our own. The excellent programs and the enthusiastic attendance indicate the desirability of continuing these meetings in some connection with the Academy. These successful meetings raise the question of our seeking similar associations with still other Societies—Societies in which many of us have membership or interest.

While such a plan would create an Orthopaedic Congress which would somewhat prolong the time consumed by our annual meetings, it would serve the purpose of uniting similar interests and of eliminating the duplication of meetings, numerous journeys, and the loss of time from our professional activities at home.

The excellent pattern set by The Journal of Bone and Joint Surgery clearly indicates that the Academy and other Societies should give careful consideration to this plan. Always of a high quality and now serving many Societies, this Journal is one of the world's leading scientific publications and has become the greatest single force in uniting together for their mutual benefit all who are concerned with the crippled and the disabled. Would not similar mutual benefits be provided by collateral or simultaneous meetings of the smaller special Societies with our annual Academy Meeting?

THE TEACHING OF ORTHOPAEDIC SURGERY

Teaching the undergraduate has been an important means of making the student acquainted with the ramifications and interests of our specialty. Traditionally, Orthopaedic Surgeons have given instruction concerning the diseases and the deformities of the musculoskeletal system, the treatment of fractures and other injuries, and the care of the physically disabled. They have also had a large part in directing the education of those ancillary technical assistants who have become associated with this treatment.

The present tendency of medical schools to shift the curriculum toward a more generalized and less specialized education, and the invasion of our field by other disciplines, seriously threatens our influence at the undergraduate level. Additionally, the emphasis placed upon research by the universities has led to the practice of replacing retiring department chairmen possessed of clinical talents by those whose chief concern is that of research in Orthopaedics. Unless we give an equal attention to the instruction both in the research and the clinical aspects of our specialty, we shall lose still further influence in holding together and in promoting our specialty.

Most of us heartily approve of the new trends in the education of the medical student. However, we must give to them our special attention in order to make certain that our specialty is properly integrated into the program. In this respect we would now be in a much stronger position if we had given our full support to the advice of LeRoy C. Abbott and of our past-president, William T. Green. They have emphasized the importance of obtaining for Orthopaedic Surgery in the university a major departmental status along with an independent financial support. The Academy might well reflect upon the means of presenting a united front in the implementation of these suggestions.

Teaching at the graduate level presents problems of a different nature, problems which lie almost entirely within our own domain. The graduate student, having made his choice of profession, comes under our tutelage to be molded into an Orthopaedic

Surgeon. How well his tutors fashion the mold will determine the whole future course of Orthopaedic Surgery.

We have been aware and highly critical of the limitations of the training programs of the past. Many of our graduates exhibit the fact that too great an emphasis has been placed upon the therapeusis and the mechanical surgical arts and not enough upon the fundamental aspects of our specialty. That our past tutorship has, however, obtained some degree of excellence is affirmed by the eminence of our specialty and by the attributes of many of the members of our profession. That it requires a progressive improvement to keep abreast of the advance of medical and social science, no one will deny. For this reason, in our present training programs more attention is now being directed toward the teaching of the fundamentals and toward research and to broadening the general medical knowledge of our graduates.

These additions are beneficial to our training program and necessary to the growth of our specialty. We must add the new ideas, but let us at the same time cling tenaciously to our excellent program in clinical training. In addition, if we are to continue to manage the total care of our patients, we must give much more instruction in the physical and social measures to be employed in the rehabilitation of the crippled and the disabled.

This is a large and difficult program, but after all, perfection in the management of our patients is our ultimate goal. For most of us in the Academy, the art and practice of Orthopaedic Surgery is our chosen profession. The responsibility for carrying out the training program falls heavily upon the Orthopaedic Surgeons in the university and in those hospitals which have facilities for teaching. Many other medical colleagues outside of the field of our specialty have also materially assisted in this program. However, as the sole means of perpetuating our specialty, the training program becomes the concern and should have the interest and support of every Orthopaedic Surgeon.

The American Board of Orthopaedic Surgery has been a major factor both in the stimulation and in the coordination of the training program. This is a democratic board whose members are chosen from among the nominees elected by The American Orthopaedic Association, Section on Orthopaedic Surgery of the American Medical Association, and by this Academy. Our ideas and our opinions should be freely expressed to the Board who should give to them serious consideration. Only in this manner may the Board receive the benefit of our collective thinking concerning the training of the Orthopaedic Surgeon. An attention to collective thought is a means of dissipating narrow points of view and a deterrent to an inflexible regimentation. Perhaps we may even look forward to the time when regardless of the disciplines of training, the ability to pass a comprehensive examination will be the only requirement for qualification in a specialty.

INTER-MEDICAL RELATIONS OF ORTHOPAEDIC SURGERY

In recent years, both the medical profession and medical sociologists have placed great emphasis upon what is known as the "total care" of the patient. This attitude is a natural reaction to specialism. The Orthopaedic Surgeon is well aware that specialism may afford a care too limited for the general welfare of the patient. The correction of this abuse will often call for the services of physicians in many fields of medicine. They are employed as a team of therapists in the management of the patient. We hold to the opinion that it does not require the creation of a new medical discipline to provide direction of the team. Rather, with each patient, this function should be performed by the physician whose qualifications best fit him for the major task at hand. In a program of "total care" all other physicians and ancillary technical workers should be subservient to the director of the program for the individual patient. Only in this manner may conflicting treatment and a duplication of services be avoided. In every instance medical problems should be directed by medical and not by quasi-medical or lay personnel.

The pursuit of this policy will make for amicable relations between medical colleagues.

Each will find that he will have the direction of those patients whose needs for treatment fall chiefly into his own discipline. Since the services of many physicians are needed, all must learn to work together harmoniously and to recognize their limitations.

Frequently, at present, too many uncoordinated disciplines both medical and lay are employed in the care of the handicapped. Often the patient is seemingly dissected and dismembered by the overly enthusiastic attack of these workers. They give to the program the very appearance of the super-specialism which "total care" was to have abolished.

In most areas in our country, the Orthopaedic Surgeon has a prominent part in the management of trauma to the musculoskeletal system. In this treatment we also need to maintain a close connection with our surgical colleagues in other specialties. If the Orthopaedic Surgeon will, at his local hospital level, work with his colleagues and still take the initiative in creating teams of specialists for the treatment of trauma, we may be reasonably assured of protecting our vested interest in this branch of our specialty.

Our past experience with and our deliberations concerning Rehabilitation and Physical Medicine and the creation of a Sub-board for Trauma under the American Board of General Surgery indicate that our specialty has kept itself in a too isolated position in reference to other fields of medicine. This is difficult to understand as we all belong to our component local and state societies, many other smaller societies, the American Med ical Association, and additionally, more than one-third of the members of this Academy belong to the American College of Surgeons. In the latter two societies, excellent Orthopaedic programs have had as their participants many of the members of this Academy. Additionally, the Academy has official representation on the Board of Governors of the American College of Surgeons, and is also unofficially represented by members of our Academy who serve on an Advisory Board of Orthopaedic Surgeons in the American College of Surgeons. In addition, the Regional Courses on Fractures and Trauma of the American College of Surgeons have had a large participation by members of our specialty. The fact that we still enjoy an isolated position in spite of these activities indicates that our participation in general medical affairs is insufficient and that we may well reflect upon a means of improving our public relations with medicine in general.

SOCIO-MEDICAL AND MEDICAL ECONOMIC PROBLEMS IN ORTHOPAEDIC SURGERY

Regarding the socio-medical and the medical economic relationships of our specialty, Orthopaedic Surgery has had much experience. Our long association with the public care of the crippled child has brought us face to face with socialized medicine. Initiated for the care of the indigent crippled child, this program has been expanded to include virtually all of the crippled and disabled under the age of twenty-one years. The financial means test has undergone a constant revision upward, thus threatening with extinction the private practice of the Orthopaedic Surgery of childhood. The uncontrolled addition of ancillary medical technical services and of social services has progressed at an alarming rate. These services are often carried out without proper medical direction. The insidious growth of this program has created a social bureaucracy which is presently engaged in the business of dispensing medical care to the crippled child. In this program all costs are met at current rates with the exception of those for medical care. The latter costs are met by a sub-standard fee schedule.

Orthopaedic Surgeons are not without fault in this program. Services have been concentrated under the care of the few to the exclusion of many of their colleagues. Physicians in school or clinic services have prescribed for the private patients of other physicians when their function should merely have been concerned with the interpretation of medical orders to an ancillary technician.

The correction of the general abuses of this program can only be obtained through an organized group of Orthopaedic Surgeons but the correction of the faults of a medical nature must come purely from within our own profession.

Fortunately, through the wisdom of some of the members of this Academy and, in conjunction with The American Orthopaedic Association, there was created the Joint Committee on the Public Care of Crippled Children. Through its excellent work, this committee has brought considerable order to the previously chaotic state of this and other programs for the care of the crippled child.

In addition to the public, Federal and State programs, we have been confronted with many other programs of a quasi-public or private nature, Societies such as the National Foundation for Infantile Paralysis, the United Cerebral Palsy Association, and the National Society for Crippled Children and Adults, to name but a few of the many. These programs are supported by private subscription and are therefore outside of our direct control.

We recognize the great work of these organizations and have played a large role in their success by our management of the medical care of the patients to whom they have given aid. While lacking a control we may, by our participation in these activities, exert a medical influence upon these organizations. In such participation, we assume a grave responsibility toward both the lay public and our own profession. We should, therefore, concern ourselves with the method of operation, with the financial structure, and with the ethical practices of these organizations. Wasteful expenditures for administrative operation, unnecessary and unsupervised programs of therapy, and other unethical practices should receive our public condemnation.

At the present time, we are faced with a still greater problem, that of the public program for rehabilitation. From our past experience with the public program for the crippled child, we can readily forecast the future of this one.

A joint committee on rehabilitation should be formed at once so that this time we will be prepared to meet our problem with a direct frontal attack rather than waiting until it is too late for anything other than a delaying action.

CONCLUSION

The opinions which have been presented are dictated by the experiences of both the past and of the present. They are concerned with but some of the many problems with which Orthopaedic Surgery is presently confronted. Out of these experiences comes the full realization that the solution of our problems will demand the full participation of all Orthopaedic Surgeons. The constant growth of the membership of this Academy indicates the important position of our specialty. The rapidly expanding attendance at our Scientific Assemblies gives evidence of our interest toward the improvement of scientific aspects of Orthopaedic Surgery.

By contrast, the meager attendance at our Executive Sessions and our general disinterest in the deliberations of our committees gives evidence that we, as a whole, are either unaware of or unconcerned with the future of our specialty. Our unfavorable position in the field of inter-medical relations and in matters concerning the socio-medical and medical economic aspects of our specialty indicates that we are too willing to accept the work of a few of our members and unwilling to work for the maintenance of the present healthy position of our specialty. Should we not stop to think of the future position of Orthopaedic Surgery? Now, as never before, we are confronted by the depredations being made upon our specialty by other fields of medicine. Additionally, we are faced with the subdivisions and the subtractions suggested by special groups within our own specialty.

Upon our part, it requires but little of our imagination to picture the future of an Orthopaedic specialty deprived of the care of crippled children, of poliomyelitis, of cerebral palsy, of arthritis, of amputations, of other muscular disorders, of trauma, and of the management of the rehabilitation of our crippled and disabled patients.

Do we not have for our guidance the experience of another field of surgery broader and larger than our own?

Have we forgotten the importance of our National motto *E Pluribus Unum*? Do we not know that divided we may fail to maintain our specialty?

In considering our future and the remedy for the correction of our present precarious position, experience clearly indicates that in this great Academy we have at our command the very means by which our problems may be met.

The Academy is well organized and has an excellent Central Office. This Office under able management is ready and willing to assist us at all times. In our Executive Sessions, through the newly added Article XII of our Constitution and By-Laws, we have a Resolutions Committee which will permit of a free discussion of our problems.

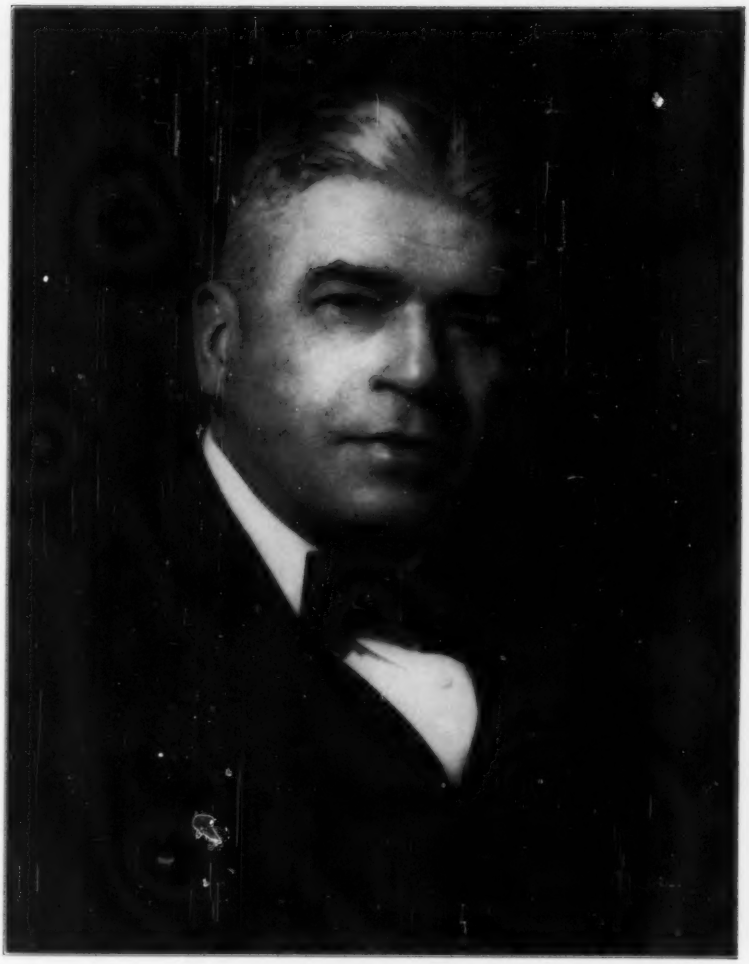
Additionally, we have many committees such as the Committee on Public Relations, the Committee on Fractures and Traumatic Surgery, the Liaison Committee to Medical and Ancillary Specialties, the Joint Committee on the Public Care of Crippled Children, and the Joint Committee on Education and Training in Orthopaedic Surgery. The meetings of these committees are open forums before which there should be a wide participation by our members.

Through our members, we have a wide representation, both official and unofficial, in many other medical societies.

Since our experience has also demonstrated that lack of communication between us is one of our own serious faults, it is suggested that our Bulletin be used more freely for this purpose. Now published quarterly, it could become the ideal forum for the presentation of our ideas and problems and could be published more frequently.

The rapid growth of Socialism which grips our specialty makes it imperative that this Academy now give its consideration to the formation of a Committee on Socio-Medical Affairs and Medical Economics. This should be a large central committee to consist of those from among our members who would be officially selected as representatives by every other Orthopaedic society in our Country. This committee would give us a regional and organizational representation which could not fail to keep Orthopaedic Surgery ahead of the rapid developments in our field.

It is your President's considered opinion that both as individuals and as an Academy united for the good of Orthopaedic Surgery, we must maintain an alertness toward the problems of our specialty. If, in the solution of our problems, we will use the many facilities of the Academy and will communicate freely with our fellow members, then and then only may we proudly answer the question, "Whither Goest Thou, Orthopaedics?" with but a single word—Forward!



ELVEN J. BERKHEISER, M.D.

1887–1958

No formal notice can convey the personal qualities which endeared Elven J. Berkheiser to multitudes of students and his many friends. His well organized mind was stored with knowledge which was always at the service of any sincere inquirer. He was easy to approach, kind and thoughtful, sympathetic in understanding, and wise in counsel. A jolly humor and keen wit leavened his advice, as they did his usual conversation. He was an excellent teacher and his students were devoted to him. It is no wonder that today many colleagues and former students remember "Berk" with pride, affection, and gratitude, having found in his friendship and his example fresh inspiration and courage in the practice of medicine.

Dr. Elven J. Berkheiser was born in Denver, Indiana, on August 23, 1887. He received his A.B. degree from Lake Forest College in 1909 and obtained his medical education at Rush Medical College, graduating in 1914, having also been elected to Alpha Omega Alpha, honorary medical fraternity. Following an internship at the New Haven General Hospital, he served during World War I as Captain in the Medical Corps, after which he became associated with Dr. John Ridlon of Chicago. On December 7, 1921, he was married to Gladys Sykes.

His skill in the field of orthopaedic surgery was quickly recognized, and he served as an Attending Orthopaedic Surgeon at the Cook County Hospital between 1924 and 1946 and later as a consultant until his death on January 3, 1958. He was Chief of the Orthopaedic Service at the Presbyterian Hospital from

1933 to 1957. His services as a consultant were constantly sought, and for twenty-two years he was affiliated in this capacity both with the Municipal Tuberculosis Sanitarium of Chicago and with the United States Public Health Marine Hospital. He taught orthopaedic surgery at Rush Medical College and at the University of Illinois for many years, retiring from the latter as Professor Emeritus in the Department of Orthopaedic Surgery. He was on the staff of the Children's Memorial Hospital from 1919 to 1930, the last five years as head of the Department of Orthopaedic Surgery. In 1954 he received an honorary degree of Doctor of Science from Lake Forest College.

His membership in leading medical organizations included The Chicago Orthopaedic Society, Clinical Orthopaedic Society, The American Academy of Orthopaedic Surgeons, and The American Orthopaedic Association.

C. N. P.

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(*Continued from page 654*)

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Proceedings

THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS

The Twenty-fifth Annual Meeting of The American Academy of Orthopaedic Surgeons was held at the Waldorf-Astoria, New York City, February 1 through 6, 1958, under the Presidency of Dr. Frederic C. Bost.

At the Second Executive Session, the new President, Dr. H. Relton McCarroll, St. Louis, Missouri, was inducted into office; the following officers and committeemen were elected:

President-Elect: Harold A. Sofield, M.D., Oak Park, Illinois;
Vice-President: William M. Roberts, M.D., Gastonia, North Carolina;
Treasurer: Jesse T. Nicholson, M.D., Philadelphia, Pennsylvania;
Secretary: Clinton Compere, M.D., Chicago, Illinois;
Librarian-Historian: Albert C. Schmidt, M.D., Milwaukee, Wisconsin.
Executive Committee:
Harold B. Boyd, M.D., Memphis, Tennessee;
Walter P. Blount, M.D., Milwaukee, Wisconsin;
William T. Green, M.D., Boston, Massachusetts;
Frederic C. Bost, M.D., San Francisco, California.
Junior Members of the Executive Committee:
Ernest M. Burgess, M.D., Seattle, Washington;
Philip D. Wilson, Jr., M.D., New York, N. Y.
Member of Membership Committee: John H. Moe, M.D., Minneapolis, Minnesota.
Member of Committee on Scientific Investigation: Vernon L. Nickel, M.D., Los Angeles, California.
Member of Committee on Public Relations: Lee Ramsay Straub, M.D., New York, N. Y.
Member of Committee on Instructional Courses: Paul R. Lipscomb, M.D., Rochester, Minnesota.
Member of Committee on Audio-Visual Education: F. Garrett Pipkin, M.D., Kansas City, Missouri.
Nominated Representatives to the American Board of Orthopaedic Surgery:
George Hammond, M.D., Boston, Massachusetts;
Sam W. Banks, M.D., Chicago, Illinois.

Dr. Carroll B. Larson was appointed Chairman of the Program Committee.

The next Annual Meeting of The American Academy of Orthopaedic Surgeons will be held in Chicago, Illinois, January 24 through 29, 1959.

Summaries of papers presented at the Scientific Sessions follow:

The Practical Importance of Synovial-Fluid Analysis. Dr. J. George Furey [1], Dr. William S. Clark [2], and Miss Katherine L. Brine [3] reported 100 cases of joint disease in which they have analyzed the synovial fluid. They did mucin, blood cell, and sugar analyses and found essentially the same distribution and characteristics of the diagnoses and fluid in their series as did Ropes and Bauer in their book.

The Extra-Osseous and Intra-Osseous Blood Supply of the Talus. Dr. Robert A. Haliburton [4], Dr. C. Roger Sullivan [5], Dr. Patrick J. Kelly [6], and Dr. Lowell F. A. Peterson [7] confirmed the work of Wildenauer (1950) concerning the arterial supply to the talus. They described a study of fourteen specimens from the arteries which course primarily posteriorly and inferiorly into the talus, being derived either from the posterior tibial artery or from the peroneal, lateral malleolar, or dorsalis pedis arteries. The main supply to the body of the talus enters inferiorly from the tarsal sinus and tarsal canal. This finding is in some disagreement with previous descriptions which describe the main supply of the talus from the dorsum, which the authors find minor.

Growth in Transplanted Bone. Dr. Charles F. Thompson [8], Dr. Edward V. Schaffer [9], and Dr. Frank B. Throop [10] stated that their interest in growth of transplanted epiphyses and epiphyseal cartilage arose from observation of a transplanted metatarsal as a replacement for congenital absence of the

1. 25100 Euclid Avenue, Cleveland 17, Ohio.
2. 2065 Adelbert Road, Cleveland, Ohio.
3. 2065 Adelbert Road, Cleveland, Ohio.
4. Medical Arts Building, 1011 Oullette Avenue, Windsor, Ontario, Canada.
5. Mayo Clinic, Rochester, Minnesota.
6. Mayo Clinic, Rochester, Minnesota.
7. Mayo Clinic, Rochester, Minnesota.
8. 23 East Ohio Street, Indianapolis 4, Indiana.
9. 23 East Ohio Street, Indianapolis 4, Indiana.
10. 3301 North Meridan Street, Indianapolis, Indiana.

proximal portion of the fibula in an infant boy. The transplantation was performed at the age of six months. Union with the fibula was apparent after four months and a year later it was estimated that the length of the transplant was equal to the length of the metatarsals in the foot. However, growth of the fibula did not keep pace with the growth of the tibia and surgical lengthening of the fibula was performed at three years of age. Five years and three months following transplantation, the tibia of the affected leg was two centimeters shorter than the opposite tibia and the fibula was five centimeters shorter than the opposite fibula. They pointed out that the growth potential of the transplanted metatarsal was much less than the normal fibula and also that the ossification center of the epiphysis of the transplant antedated the ossification centers in the metatarsals of the foot by some three months, suggesting earlier maturation of the transplanted metatarsal. This clinical observation was followed with the report of a series of experimental transplants in dogs and rabbits. Autogenous and homogenous transplants of the epiphysis and epiphyseal cartilage of the metatarsal to the proximal portion of the fibula and from there to the metatarsal were carried out. They concluded from the study that in dogs autogenous transplants could continue to grow in length whereas homogenous transplants failed to survive regardless of whether the donor was a foetus near full term, newborn puppy, or litter mate from five to eight weeks of age.

Changes in Respiratory Function with Scoliosis. Dr. Thomas Gucker III [11] stated that clinically serious loss of vital capacity in a ten-year-old patient following cast correction and spine fusion for scoliosis stimulated him to study the respiratory function of patients with scoliosis. He reported on twenty-three patients treated in casts, in Milwaukee frames, and by spine fusion. In the poliomyelitic patients before treatment the average vital capacity was 64 per cent of the predicted normal, which was further reduced an average of 21 per cent by cast correction. In the idiopathic scoliotic patients with an average of 80 per cent of predicted, 29 per cent was lost. Thus weight is added to the increasing recognition of the serious involvement of respiratory function in patients with scoliosis particularly when paralytic. The adverse effects of cast correction on breathing capacity may be critical if scoliosis has already produced serious reduction in respiratory function.

Calcinosis Circumscripta. A Local and Metabolic Study. Dr. Robert W. Bailey [12] reported studies of a patient with calcinosis circumscripta. The object of the study was to gain additional information on the pathophysiology of the calcium deposits which occurred in ectopic locations in this patient. The diagnosis was scleroderma and Raynaud's phenomenon with ectopic calcification characterized as calcinosis circumscripta. The pathogenesis of this syndrome was discussed by the author.

The patient was a woman, sixty-three years old, with a ten-year history of Raynaud's phenomenon, sclerodactylia, and numerous areas of soft-tissue calcification in both the hands and the right elbow. Four years after the onset of the disease, she had begun to observe small whitish nodules appearing along the palmar aspect of her fingers and about the right elbow. These deposits in her right index finger limited motion so that surgical removal of the ectopic calcific deposit was performed in 1950. Similar calcified masses were removed from the interscapular area. From 1950 to 1953 the patient had numerous laboratory studies performed and was treated with various drugs including priscoline, quinine, ACTH, and cortisone, all without benefit, while restriction of motion in the right elbow and the fingers of both hands became increasingly troublesome. On several occasions, the white nodules beneath the skin became inflamed and discharged variable amounts of toothpaste-like material. The patient moved to California in 1955 seeking a more temperate climate. This gave some relief from the Raynaud's phenomenon. Basal metabolic determinations, serum calcium, serum phosphorus, alkaline phosphatase, and calcium balance studies were within normal limits. While under study at the University of California Medical Center, biopsy specimens of bone, calcareous deposits in and beneath the skin and the skin itself were obtained and results reported. In general the ectopic calcifications seemed to be associated with degeneration and death of muscle cells and increased thickness of the dermis with disappearance of subcutaneous fat. After these biopsy specimens were obtained, sodium versenate was administered during two test periods of twenty and thirty days. Duplicate biopsies of dermis calcification and bone and muscle calcification were removed following completion of the kelate administration.

The calcium percentage of the ash weight of the specimens was the same before and after treatment. Also there was no difference in the calcium percentage of the ash in bone or ectopic calcium deposits. During the administration of sodium versenate, the urinary calcium excretion increased from about 100 to 300 milligrams for twenty-four hours and no effect on fecal calcium excretion was noted. Auricular fibrillation occurred after the first twenty days of versene administration and recurred after the second thirty-day period of the use of this drug. Despite this cardiac irregularity, no significant change in the blood calcium or phosphorus was reported, although the author thought the cardiac irregularity suggested a disturbed "calcium homeostasis."

The author concluded that calcinosis circumscripta is probably not in itself a systemic metabolic dis-

11. 3400 Spruce Street, Philadelphia 4, Pennsylvania.
12. 1313 East Ann Street, Ann Arbor, Michigan.

ease, but is more likely a disturbance of the local metabolism of degenerating connective tissue and muscle. It is pointed out by the author that calcifiability is acquired by tissues which normally do not calcify and that these tissues are slowly degenerating with reduced viability on a vascular basis in scleroderma with Raynaud's phenomenon. Dr. Bailey concluded from his studies that the amorphous calcium phosphate deposits are unaffected by a powerful kelating substance in the circulating blood and may be inaccessible to it. He stressed the conclusion that systemic treatment with sodium versenate in his patient did not remove calcium preferentially from the pathological deposits.

The Phasic Activity of the Muscles of the Lower Extremity and the Effect of Tendon Transfer. Dr. J. Robert Close [13].

Femoral-Shaft Fractures in Children. Evaluation of Treatment by Early Manipulation and Double-Spica Immobilization. Dr. Thomas B. Dameron, Jr., and Dr. Hugh A. Thompson described a method of treatment for femoral-shaft fractures in children which has been used successfully in Raleigh, North Carolina, for twenty-two years. The method requires fixed traction with a Kirschner wire through the proximal portion of the tibia, manipulative reduction, and the application of a double spica which affords countertraction through the opposite foot. The advantages claimed for this method included its simplicity, early discharge after twenty-four hours of hospitalization, and consistently good results.

The records of 100 unselected patients were reviewed, fifty-three of whom returned for follow-up evaluation at from one to twenty-two years (average 6.9 years) after the fracture. The ages ranged from six weeks to fourteen years, but only four patients were over ten years of age. Kirschner wires were not used in every patient and in no patient under two years of age. Plaster immobilization was continued for eight to ten weeks. There were no known deformities and no loss of function. A few patients noted aching in inclement weather and one noted increased fatigability on strenuous activity. Follow-up roentgenograms showed no clinically significant angulation. Minor angulation was not always corrected by growth. In children under nine years of age with side-to-side apposition of the fracture fragments the contour of the femur was usually normal after three years. The length of the extremities was compared at follow-up examination both clinically and by roentgenographic measurement. An average increase in length of the affected extremity of one-sixteenth of an inch was found with a range between nine-sixteenths of an inch of overgrowth and one-half of an inch of shortening. It was the authors' impression that transverse fractures in children under six years of age consistently cause overgrowth while little overgrowth followed oblique and spiral fractures or fractures in children over eight years of age.

Closed-Space Infection Following Removal of Lumbar Intervertebral Disc. Dr. Arthur A. Thibodeau [16] and Dr. Joseph K. Maloy [17] reported fourteen cases of postoperative infection of the bone and space following removal of a lumbar intervertebral disc. This infection causes a poor result, may be difficult to diagnose and treat, and is not a rare sequela. The clinical features of this complication are: an asymptomatic period of a few days to six weeks following the operation, the development of severe back pain, and the relative absence of systemic reaction or evidence of infection in soft tissues of the back. Three patients with draining sinuses were exceptions. The roentgenographic findings are non-contributory for two to three weeks following the removal of the disc; then the bone of the adjacent vertebral bodies shows irregularity and loss of trabecular pattern followed by narrowing of the interspace, advancing bone destruction, new-bone formation, and increased density. In three patients, fusion of the involved bodies occurred. Treatment consisted in administration of antibiotics to patients with acute symptoms, immobilization in a bilateral plaster hip spica, followed by ambulation in a plaster jacket or back brace for long periods of time. In three patients, drainage and débridement was done through a retroperitoneal approach. *Staphylococcus aureus* was cultured from drainage material from one patient. Four patients followed over two years since onset of the infection still had back pain, were easily fatigued, and had moderate to marked reduction in working ability. The end result had not been determined in the remainder.

Patellectomy: Extensor-Tendon Mechanism Repair. Dr. Howard B. Shorbe[18] and Dr. Chauncey H. Dobson[19] stated that the indications for patellectomy are commonly recognized, but no specific technique is a method of choice. Fifty years ago Murphy described a procedure in which a flap of the quadriceps tendon and muscle was used to reinforce the defect left by removal of the patella. Since then variations of this method have been reported. In 1949 Dr. Shorbe initiated a similar procedure which may be used in most patients in whom patellectomy is necessary which provides strong closure, results in a short convales-

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18. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.
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cence, and gives good functional and cosmetic results. After removal of the patella, an inverted V incision is made through two-thirds of the thickness of the quadriceps tendon. The V flap is folded downward over the patellar defect and is sutured to the patellar tendon and knee-joint capsule. The defect created in the quadriceps tendon can be partially closed. Postoperatively the knee is immobilized for three weeks. Chondromalacia and fracture of the patella were the two most common indications. V-plasty yielded predominantly good results in six operations for chondromalacia and predominantly good and fair results in six patients with fractures. The authors concluded that this operation consistently produced good results in all types of cases.

Aseptic Necrosis of the Femoral Head. Effect of Treatment by Drilling and Bone-Grafting. Dr. Michael Bonfiglio [20] and Dr. Maxwell Bardenstein [21] treated during the past seven years fifty-three patients with varying amounts of aseptic necrosis of the femoral head, with or without non-union of a fracture of the femoral neck, by the insertion of two autogenous cortical-bone grafts. The grafts are placed in the superior-anterior quadrant of the femoral head—giving support to the area most likely to collapse. In most instances a tibial graft from the same extremity is used, although in a few a split fibular graft was employed. Three five thirty-seconds of an inch threaded Steinmann pins were used for additional fixation, being inserted below the grafts, when non-union was present. The evaluation of the fifty-three patients (fifty-five operations) was based on examination two years to six and a half years after operation. The results showed the procedure to be effective in restoring continuity to the ununited fracture of the femoral neck and viability to the necrotic femoral head in a sufficiently high number of instances to warrant its consideration in the management of these complications.

Presidential Address. Dr. Frederic C. Bost [22]. (See page 707.)

Reversibility of Pre-Gangrene in the Severely Ischaemic Limb. Dr. A. W. Humphries [23], Dr. V. G. DeWolfe [24], and Dr. F. A. LeFevre [25] described two anatomical patterns of vascular occlusion—segmental and non-segmental. Only the segmental occlusions are amenable to surgical treatment since the vessel is patent both above and below the limits of the occlusion.

Sudden total occlusion of the main artery of an extremity will result in an ischaemic limb since collateral circulation does not have time to develop. In these limbs early definitive arterial surgery is imperative—embolectomy or thrombectomy with repair of the original vessel or replacement of certain portions of it by arterial grafting. The authors reported a series of thirty-four embolectomies with only one unsuccessful result when done during the first twenty-four hours, with 50 per cent successful results at forty-eight hours, and with one successful result at eighty-three hours.

Slow progressive occlusion is a much more common cause of ischaemic limbs. Intermittent claudication is the first symptom of decreasing blood supply to the leg. The development of ischaemic rest pain indicates further reduction in blood flow.

Arteriograms usually demonstrated the type of vascular occlusion. If the arteriogram was equivocal, surgical exploration of the vessel at the distal end of the occlusion was carried out, and arterial grafting was done if there was adequate flow of blood from the distal end of the artery. Sympathectomy was also done if the blood flow was low.

The authors presented a series of arterial grafts in seventy-one consecutive ischaemic limbs with a follow-up period up to four years. This series was compared with a similar group of sympathectomies for ischaemia done prior to the advent of arterial grafting. In about one-half of the patients in whom sympathectomy was done the legs were salvaged, but very few were also relieved of claudication. Of the patients in whom grafting was done the legs were salvaged in more than three-quarters and of these the great majority were also relieved of claudication. The inevitability of amputation in the severely ischaemic leg must now be re-evaluated in the light of the present practicability of arterial grafting.

Management of Brachial-Plexus Injuries (Traction Type). Lt. Col. Earl W. Brannon [26] and Major John F. Tracey [27] reported a careful review of sixteen patients with traction injuries to the brachial plexus. They were observed on the Orthopaedic Service at the Lackland Air Force Hospital in a twenty-four-month period. The mechanism of the injury was discussed. Sufficient traction force applied to the brachial plexus will produce stretching, tearing, or rupture of the important structures. The upper plexus is injured when the arm is thrown backward and adducted or if the shoulder is depressed. The plexus is actually drawn away from the spinal cord. If the arm is overhead, the lower plexus is affected. Damage may occur at any level of the nerve roots, trunks, divisions, or cords.

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The classification of the brachial-plexus injuries was discussed. According to the authors, the classification involving the fifth or sixth cervical segments is known as the upper or Duchenne-Erb type and that involving the eighth cervical and first thoracic segments is called Klumpke's paralysis. A third, or combined type, adds the involvement of the seventh cervical-nerve roots to either upper or lower or both implying a more extensive injury. A second category is based on the conception of Hendry who considered it impossible to classify the residual paralysis on the basis of nerve root unless the paralysis corresponded to a peripheral nerve loss equivalent. Ordinarily the residual involvement is not so clearly defined. Hendry classified the paralysis on the basis of functional involvement of hand, wrist, forearm, elbow, and shoulder. The authors followed the work of Murphy. They employed myelography in each of the cases and found that the neurological deficit usually was greater than the demonstrable avulsion. The management of these cases followed this general pattern. At the time of the initial injury, support of the involved parts is necessary to reduce further traction effect. This is accomplished by balanced shoulder suspension or a shoulder splint. On the hand dynamic splinting is used. Active and passive exercises are instituted to maintain joint mobility and prevent contractures. A myelography is done as soon as the patient's condition permits and the avulsion of the roots is interpreted from the demonstration of opaque oil migrating through the intervertebral foramina into the traumatic diverticuli lying extraspinally. In nine of the sixteen patients in the series positive myelograms were obtained. Only one patient had residual tota paralysis for which amputation might be indicated. Consideration was given primarily to certain basic requirements for function, namely, a stable shoulder, a flexible elbow, an opposable thumb, and grasp. The reconstructive procedures included shoulder fusion, flexorplasty, bone block for thumb opposition, flexor tenodesis, opponensplasty, and transplantation of the wrist flexors to finger extensors. Twelve of the sixteen patients were returned to military duty in their primary assignments. A plea was made for utilization of diagnostic myelography and early reconstructive surgery in avulsion cases.

Congenital and Developmental Defects of the Neck of the Femur. Dr. Edward A. Millar [28] and Dr. Harold A. Sofield [29] described and classified twenty-four cases of defects of the femoral neck listed under the term *coxa vara*. Although all had considerable similarity in the roentgenographic appearance, namely a lack of osseous continuity of the femoral neck and a decrease of the angle of the neck and shaft, there were many causes of the defect. These were classified as follows: (1) congenital coxa vara, (2) traumatic birth injuries of the femoral neck, (3) defects of the femoral neck associated with spina bifida vera, and (4) defects of the femoral neck which were localized manifestations of generalized alterations in bone growth. In this last category were included defects associated with chondrodystrophy, osteitis fibrosa cystica, osteomalacia, and congenital pseudarthrosis of the femur.

It was pointed out that congenital coxa vara is the most common cause of this group of deformities and that coxa vara is but one stage of defective maturation of the femur which ranges all the way from a congenitally short femur to complete absence of the entire femur.

The history of untreated congenital coxa vara was well demonstrated by a series of films extending over the years 1927 to 1956. The severity of the structural changes due to increasing coxa vara can be minimized by repeated osteotomies. The limb-length discrepancy is a secondary factor which must be considered when one extremity only is affected. Whereas the deformity in congenital coxa vara tends to increase, the deformity following traumatic injuries tends toward correction of the defect. In these cases the linear growth of the femur is not usually severely affected. Most interesting were the patients with associated spina bifida vera. Roentgenograms were shown which demonstrated that the femoral neck was intact prior to the subsequent development of true pseudarthrosis of the neck of the femur. The management of these patients was given in detail.

The Use of Intravenous Priscoline in the Treatment of Subdeltoid Bursitis. One-hundred and fifty patients who complained of severe pain in the region of the shoulder joint had been treated by Dr. C. J. Frankel [30] and Dr. D. V. Strider [31] by the intravenous injection of twenty-five milligrams of priscoline hydrochloride (one cubic centimeter) daily for one, two, or three days. When three injections of priscoline fluid failed to give relief, one cubic centimeter of hydrocortisone and four cubic centimeters of one per cent xylocaine were injected locally into the bursa.

Results were graded excellent when there was complete relief and abduction and rotation were painless and as free as before the onset. In this group there were seventy-one (47 per cent). A good result was one in which sedation was no longer required and painless abduction and rotation were partially regained: sixty-eight patients (45 per cent) were placed in this group. Of the eleven patients who failed to get relief

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from the injections of priscoline, four were helped by local injection of hydrocortisone combined with intravenously administered priscoline and six were helped by hydrocortisone alone.

The details of other series treated by x-ray alone and by hydrocortisone alone and cited for comparison were insufficient. No follow-up data were included.

Priscoline should not be used when duodenal ulcer or coronary heart disease is present. The drug is reported to be antagonistic to alcohol.

Sinus Tarsi Syndrome. A Clinical Entity. Dr. Denis O'Connor [32] pointed out a rather unusual but not unduly rare condition in the ankle, usually following a sprain. After the ordinarily accepted treatment, the patient does not progress well and has persistent pain in the sinus tarsi which may last for months, or even years, and is quite resistant to the ordinary methods of treatment by physical therapy and local injection. He found that these cases were amenable to surgical correction, the exact procedure being to clean out the fat pad in the sinus tarsi and to resect the superficial ligamentous floor which he described as being the lower part of the anterior annular ligament of the ankle. He mentioned that this ligament traverses the fat pad, has fat on both sides of it, and he thought the scarring in this ligament and undue tension on the ligament from healing are the causes of pain. He said that the procedure is a simple one and that patients recover promptly. It was uniformly successful in his hands. He made the diagnosis forty-five times. Fourteen of those patients were willing to accept surgery and surgery was advised in an additional ten, which would be approximately half of the cases. In nine of the fourteen cases complete relief was obtained; in five some improvement was brought about.

Osteo-Arthritis in Relation to Types of Motion. Study of the Knee and Ankle. Dr. Hanes Brindley [33], Dr. R. A. Murray [34], and Dr. R. A. Barrow [35].

Arthroplasty of the Hip in Rheumatoid Arthritis. A Follow-up Study of Sixty-Eight Hips. Dr. J. R. Schwartzmann [36] reviewed and analyzed the results in sixty-eight hips in which arthroplasty was done for disabling rheumatoid arthritis. There were forty-eight patients studied; none of these had isolated hip-joint disease. Therefore multiple involvement of the joints complicated the problem of mobilization of the hip joint. Certain preoperative requirements had to be met before the patient was considered for arthroplasty: (1) absolute inability to control symptoms by conservative means, (2) the patient must accomplish full control of the ability to contract muscles crossing the major joints of the lower extremities in a manner to allow progressive strengthening and power in the muscles regardless of pain or absence of motion, (3) control and balance of medication and a state of health to allow the patient to withstand extensive surgery, (4) a sufficiently long life expectancy to justify such a prolonged rehabilitative program, and (5) mental and psychological attitude with aggressive desire for improvement. In twenty of the forty-eight patients arthroplasty was done on both hips; in fifty-three hips Smith-Petersen cup arthroplasties were done and in fifteen hips a Naden-Reith prosthesis was inserted. Complications encountered included two delayed breakdowns of operative wounds six and eight months after surgery. There were four cases of transient peroneal palsy. In patients in whom cup arthroplasty had been done one patient had fracture of the base of the femoral neck and one had an intertrochanteric fracture. One hip subluxated but was asymptomatic. One cup was removed because of infection. In one hip the femoral neck slipped out of the cup. In the patients in whom prostheses were used three loosened and the stems were wandering at three and five years. These would eventually require re-operation. There were two deaths. Dr. Schwartzmann believed the Smith-Petersen cup arthroplasty to be the method of choice in the management of rheumatoid arthritis.

Total Cervical-Spine Fusion for Neck Paralysis. Dr. Jacquelin Perry [37] and Dr. Vernon L. Nickel [38] pointed out that a flail cervical spine is an increasing problem for the orthopaedic surgeon due to the large numbers of persons surviving respiratory poliomyelitis and who are freed from respiratory assistance. The authors were concerned with a group of patients who recovered significant function in the extremities but who had insufficient control of the neck to achieve maximum activity. It was noted in some patients that the functions of swallowing and speaking may be impaired if the head cannot be held erect.

An analysis of the anatomy of muscles involved in holding the head erect was made, from which a functional grouping was derived. The muscles were grouped under capital flexors and extensors and cervical flexors and extensors, depending upon their function. A correlation of muscle mass with segments controlled

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indicated that the greatest mass of capital extensors overlay the axial-atlantal joint and that of the cervical extensors overlay the cervicothoracic junction. Similar studies indicated that the flexor mass was maximal at the level of the fourth cervical vertebra opposite the lordotic apex.

The cervical extensor group was found to be the most common site of paralysis. The clinical pictures of deformities secondary to paralysis in the functional groups mentioned were presented and analyzed. In addition, the importance of the capital groups of muscles in relation to impaired function of bulbar activities was demonstrated by cinefluorographic techniques.

The early prevention of deformities with neck rolls, butterfly pillows, and braces with cervical extension was stressed, and the advantages of surgery utilizing spine fusion were emphasized in properly selected instances. Cervical-spine fusion was performed with the patient in a plaster jacket incorporating a special "halo" of stainless steel which was fixed to the skull with adjustable pins to stabilize the head. Ordinarily fusion by the Hibbs technique was carried out to the level of the third cervical vertebra. If the capital extensors were weak, the fusion was extended to the occiput with iliac-bone grafts. The lower limit of fusion was usually the third thoracic vertebra. If scoliosis was a complication, the fusion area was extended to the fourth lumbar vertebra. Postoperative immobilization was maintained for a minimum of three to four months and usually up to six months.

Twenty-two cases were reported. In ten patients fusion was to the occiput, and in eleven the fusion area was extended to the fourth lumbar vertebra because of scoliosis. No instance of pseudarthrosis was reported.

The Advantages of Early Spinal Fusion in the Treatment of Fracture-Dislocation of the Cervical Spine. Dr. H. Francis Forsyth [39], Dr. Eben Alexander, Jr. [40], Dr. Courtland H. Davis, Jr. [41], and Dr. R. Underdal [42] presented an analysis of the mechanism of injury and the results of treatment of cervical spine injuries in eighty-one patients, fifty-two of whom had neurological symptoms.

Skull traction had produced more satisfactory reductions and there had been no further cord injury while it was being used during definitive treatment.

Wire internal fixation and fusion had resulted in immediate and lasting stability. Those injuries in which recurrence of deformity might be expected had been chosen for stabilization. By that means recurrence of displacement and late cord injury had been avoided. Thirty-eight of eighty-one patients had been so treated: fourteen patients of eighteen with fracture-dislocation of the first on the second cervical vertebra and twenty-two patients of thirty with dislocation underwent the fusion operation. Simple wedge compression fractures and those injuries resulting from violent extension had been treated by traction and later by external brace fixation.

Redislocation had occurred in two patients with fracture dislocation of the atlas and axis following wire fixation and fusion of the neural arches of these two vertebrae alone. The third cervical vertebra had therefore been included in the fusion and a rib or other rigid cortical graft had been firmly wired to the posterior arches on either side to prevent redislocation.

In all the fusions bone grafts had been placed under the binding wires along the bases of the spinous processes supplemented by additional match-stick grafts laid along the laminae on either side.

Results were uniformly good. The patients with fusion resumed pre-injury activities sooner and more easily than the patients without fusion. Cord injury had seriously complicated both groups.

Forsyth had carefully investigated the forces involved in the mechanism of production and found forcible hyperextension responsible in a very much higher proportion of injuries than was commonly believed. After violent hyperextension of the neck not only was the odontoid process and the posterior arch of the atlas found to be fractured but spinous processes, articular processes, laminae, or pedicles of one or more of the cervical vertebrae below, on one or both sides may also have fractured. Hyperextension fracture had occurred in the posterior elements of the cervical vertebrae without fracture of the atlas or axis. The anterosuperior lip of one of the middle cervical vertebral bodies had been found avulsed with or without fracture of posterior elements.

If the extending force had been applied with a longitudinal compression component the posterior bone elements were crushed and displaced backward and upward, especially fractured articular and spinous processes while fracture of the pedicles was not uncommon.

If the extending force is applied on one side of the face a rotatory component is introduced and the compression fractures occur in the posterior elements on one side (the opposite) only.

Forsyth pointed out that there is a strong tendency in the cervical spine to recoil following violent hyperextension and that this recoil may actually cause anterior displacement of a vertebral body the articular processes or pedicles of which were broken during the extension phase. Such a fracture-dislocation by violent hyperextension will thus simulate a fracture-dislocation caused by violent hyperflexion to which it is often

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erroneously attributed. When the rotational component is present, the recoil by causing slight unilateral anterior displacement may simulate a flexion unilateral rotatory dislocation.

It had been found best to treat these extension injuries by wire internal fixation and fusion.

Report of the Committee on Femoral-Head Replacement Prostheses. Questionnaires were sent to all members of the Academy and from these there were returned 551. Of these 453 said that they were using prostheses. Ten replies were incomplete, and eighty-eight said they were not using prostheses.

The types of prostheses now being used according to the men reporting: Moore, 195; Thompson, 134; Eicher, 76; Naden-Reith, 19; and Minneapolis, 10. There were twenty other types, all with less than ten men reporting use. In other words, there has been a definite trend away from the short-stem prosthesis to that with the long intramedullary stem. This is particularly reflected in the report of the types of prostheses formerly used. In this group the biggest change was away from the Judet type of prosthesis. The chief reasons for the changes were that the Judet type gave considerable wobble, that the acrylic and nylon prostheses either wore out or were broken, and that the intramedullary-stem type gave better stability. In all there were thirty-one reasons for this change.

The present indications for the use of replacement prostheses are primarily as a replacement in subcapital fractures in the older age group, this group being somewhere between sixty and seventy years. Next in frequency in indication were: aseptic necrosis, non-union with or without necrosis, hypertrophic arthritis, and rheumatoid arthritis. There were, in addition, twenty-five other indications.

The contra-indications for the use of replacement prostheses were chiefly: infection, acute fractures, particularly in patients under age sixty, adolescence, debility, and rheumatoid arthritis. There were forty-three other contra-indications given.

From this survey there have been inserted, by this relatively small group reporting, 10,059 prostheses as a single replacement, ninety-six for bilateral replacement, and 119 prostheses inserted by those reporting that they no longer use them. Thus there was a total of 10,274. The age range was from two years to 107 years, with the average youngest age 34.2 years, and the average oldest age 86.7 years. The longest follow-up time was 120 months, with the average longest time being 63.2 months and the average shortest time 3.5 months.

The question was asked as to how the patient was walking: this was probably not a fair question inasmuch as many men have instructed their patients to use a cane always. Also no consideration was given as to whether or not the patient may have been bedridden or in a wheel chair prior to the surgery and while still being limited to bed or wheel chair may have less pain and is an easier nursing problem. Despite this, 33.6 per cent of the major series were walking unaided and 34.4 per cent were walking with one cane. In the patients' evaluation of the results their replies were: *excellent*, 25.8 per cent; *good*, 40.8 per cent; *fair*, 20.1 per cent; and *poor*, 13.3 per cent. In the doctors' evaluation of the results: *excellent*, 23.9 per cent; *good*, 41.2 per cent; *fair*, 20.9 per cent; and *poor*, 14.0 per cent.

The chief complications were: dislocation of the prosthesis and fracture of the prosthesis itself. The Judet type broke the greatest number of times. The femur was fractured at insertion of the prosthesis 178 times and a late fracture of the femur occurred forty-nine times. Infections were reported in 254 patients and phlebitis in 157; 218 patients died.

The posterolateral approach was most commonly used (two to one) over the anterior and in most instances (nine to one) the trochanter was not removed. With fracture, the capsule was closed almost routinely but when considerable reconstruction was necessary the capsule was usually resected. There were 756 classified as total failures. The treatment of these failures was either replacement of a prosthesis by another type of prosthesis, removal of prosthesis, attempted fusion, or some further type of reconstruction such as the Colonna reconstruction. The results were never better than fair.

Of those eighty-eight who reported they were not using prostheses, there were only eleven who had ever used a prosthesis and had discontinued their use. Many men in this group have limited their practice to children, hand surgery, or are retired from practice. The chief reasons for not using prostheses were that other methods such as osteotomy, cup arthroplasty, and fusion were better, or that they had not yet had a suitable patient for the use of a prosthesis.

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The Dashboard Femoral Fracture. COL. STERLING J. RITCHEY [43], CAPT. GEORGE J. SCHONHOLTZ [44], and COL. MILTON S. THOMPSON [45] discussed the pathomechanics of femoral-shaft fractures resulting from automobile accidents, noting that different types of fractures may occur depending on the type of force ap-

43. Walter Reed Army Hospital, Washington 12, D. C.
44. Walter Reed Army Hospital, Washington 12, D. C.
45. Walter Reed Army Hospital, Washington 12, D. C.

plied to the femur and that associated injuries of the hip and knee must be searched for in every instance. The dashboard femoral fracture is peculiar to the driver or front-seat passengers of automobiles traveling at high speeds when sudden deceleration results from a head-on collision with another moving vehicle or with a stationary object. Although a variety of injuries may result including fractures and dislocations of the hips, fractures of the patella, ligamentous injuries of the knee, and maxillofacial injuries, the authors were concerned primarily with the extensively comminuted femoral-shaft fractures which occur when the thighs are abducted at the time of impact with the result that the femoral heads are firmly seated in the acetabula and therefore do not dislocate. Instead the femoral shaft crumbles under the immense longitudinal compressive force produced by the sudden deceleration (calculated to be fifty tons or more for a person weighing 200 pounds with his knees two inches from the dashboard) when the car is brought to a total stop from sixty miles per hour.

The authors analyzed thirty cases of dashboard fractures both as to the mechanism of injury and the results of treatment. All were occupants of the front seat; none were wearing seat belts. Of the thirty fractures twelve were the result of head-on collisions with moving vehicles; seventeen were due to striking fixed roadside objects; the cause of one was unknown. The average admitted speed was sixty miles per hour. The associated injuries included four comminuted fractures of the acetabulum, one fracture of the femoral neck, one impaction fracture of the greater trochanter, four contralateral femoral-shaft fractures, twenty-four ipsilateral knee injuries, six maxillary fractures, one skull fracture, three severe facial lacerations, and a variety of other less frequent injuries.

Of the thirty patients analyzed fourteen were treated by skeletal traction and sixteen were treated by open reduction. The average follow-up for patients treated by closed methods was thirty-six months, while for those treated by open reduction the follow-up averaged twenty-eight months. The average time in traction was 4.6 months and the time between the injury and the beginning of unprotected weight-bearing was ten months. In the patients treated by open reduction in whom intramedullary rods, plates, and screws were used the average time till unprotected weight-bearing was eleven months. The results were graded according to certain criteria specified by the authors. Of the patients treated by closed methods 50 per cent were graded *excellent* while only 6 per cent of those treated by open reduction were graded *excellent*. The poor results following open reduction were due to surgical complications including sepsis and failure of the internal fixation to maintain length. The authors concluded that skeletal traction is the treatment of choice for these fractures, care being taken to treat associated injuries of the knee and hip first before traction is instituted. The need for vigilance to maintain proper femoral length was emphasized. A brief discussion of appropriate measures to prevent these fractures concluded the presentation.

Fractures of Femoral Condyles. A Study of Cases Treated With a Femoral-Condyle Bone Plate. Dr. Robert B. Elliot [46] presented a series of twenty-seven fractures of the supracondylar and intercondylar areas of the femur. A newly designed femoral-condyle bone plate incorporates the V-nail principle to its condylar component. The blade incorporates the slotted-plate type of fixation for the shaft. It is of solid construction, and curved to fit the flare of the femoral condyle. The author feels that early and accurate and firm stabilization reduction of the condylar fractures allows more rapid restoration of joint function. No non-unions, infections, or serious complications were reported. The average range of motion restored was 111 degrees, and the period of hospitalization was appreciably reduced. An extensive anterolateral approach to the fracture and distal portion of the femur was made to allow total visualization of the entire lower portion of the shaft of the femur. The blade portion was then inserted into the lateral portion of the femoral condyle in the axial line of the femoral shaft with great care being taken to avoid the popliteal structures. Screw fixation of the plate to the shaft allows compression to take place at the fracture site through normal muscle action. The rigid fixation usually obtained obviated the necessity for external fixation and permitted the desired early mobilization of the knee joint.

Congenital Dislocation of the Knee. Dr. John J. Niebauer [47] and Dr. Don King [48] defined congenital dislocation of the knee as those deformities which are truly congenital and which demonstrate hyperextension of the knee; the knees usually lack normal flexion. Characteristically, there is anterior displacement of the tibia in relation to the femur. Rotatory deformity of the tibia in respect to the femur may also occur in varying degrees. In nine patients, there were fourteen deformities. Five of the knees were reduced by simple manipulation and the application of a cast. Five were reduced by traction, followed by manipulation and the application of a cast. In four knees (three patients) open reduction was done.

If skeletal traction is required, the authors recommend utilizing the traction with the baby in a prone position. This permits distraction as well as flexion of the knee. In order to better control the femur, a band was applied across the back of the infant's thigh and gradual traction and flexion were obtained. In those patients in whom open procedures were done, varied pathological conditions were encountered. In one

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instance after the patella, quadriceps tendon, and the patellar tendon were completely freed from the surrounding capsule and lengthened, the knee still could not be flexed. The suprapatellar pouch was found to be filled with fibrous tissue which was adherent to the quadriceps tendon and which extended to the surrounding capsule. This fixed the capsule to the anterior surface of the femur. The anterior capsule had to be dissected laterally from the surface of the femur, and only after the capsule had been reflected laterally over the edge of the femoral condyle could knee flexion be obtained. In this instance the knee was closed with the capsule reflected laterally. In those patients in whom reduction was obtained by conservative measures, excellent results were obtained. In those patients in whom open procedures were done improvement was obtained but some limitation of full extension and instability of the knee joint persisted.

Early recognition and treatment of this condition were recommended. The majority of patients respond to manipulation and the application of a cast or simple traction. Open procedures will be necessary only in those who have severe deformities with abnormal periarticular structures. In these something less than an excellent result will be obtained.

Considerations on the Surgical Treatment of Slipped Epiphysis with Special Reference to Nail Fixation. Prof. Gunnar Wiberg [49] discussed surgical therapy in regard to the risks of injury to the hip in patients with slipped epiphysis. The degree of slipping decided the type of operation. In slight and moderate slipping, fixation *in situ* of the epiphysis by a nail was used in 185 cases. After operation the patient was allowed full weight-bearing after about eight days. An interval of two years was judged sufficient for the determination of the end results in hips treated by nailing. Complications encountered were:

1. Driving away of the epiphysis by the nail (seven). In three, impaction overcame the diastasis and in three it disappeared with early weight-bearing. In the seventh patient the three-flanged nail was replaced by three Nystrom nails without diastasis.
2. Bending of the guide wire (three).
3. Perforation of the cortex of the femoral head by the nail (fifteen).
4. The nail may later lose its grip in the epiphysis because of true gliding or because growth of the femoral neck pushes the epiphysis away (thirty-seven). In sixteen re-nailing was necessary because the epiphyseal plate had not closed; in one a marked slipping necessitated a wedge osteotomy of the neck of the femur.
5. Fracture of the femur at the level of the nail (four).
6. Necrosis of the head (two). In one which was partial, there was regeneration, but in the other severe necrosis caused marked loss of function (this was the only poor result in 185 cases).

In this series a slipping of the epiphysis on the "good" side occurred in twenty-four patients (13 per cent). Twenty-two hips were nailed *in situ*, but in two the slipping was marked and a wedge osteotomy was done.

In patients with marked slipping, wedge osteotomy with nail or screw fixation was followed by plaster immobilization for four to five weeks. The incidence of necrosis of the femoral head was 27 per cent. The results were poor in all patients. The author recommended caution in the use of this operation and wondered if subtrochanteric osteotomy might not be a better procedure.

In conclusion, the author stated that fixation of the epiphysis *in situ* by a nail is fully acceptable, but the use of wedge osteotomy must be questioned.

Osteotomy of the Ilium with Rotation of the Acetabular Roof for Congenital Dislocation of the Hip. Dr. Paul A. Pemberton [50] reported his experience with an operative procedure designed to increase the depth of the acetabulum by turning down the entire acetabular roof from the side of the ilium. This procedure had been performed on fifty hips in forty patients during the past few years. Most of the patients had previously untreated congenital dislocation of the hip. Five of the patients had dislocation of the hip associated with spina bifida or poliomyelitis. The youngest patient operated on was eighteen months old and the oldest was forty-nine years old.

The operation consists essentially in a radical shelf operation in which the entire acetabulum is turned down from the wing of the ilium. The hip joint is approached through an iliofemoral incision. The muscles are reflected subperiosteally from the ilium, exposing the joint capsule. The osteotomy is begun just above the anterior-inferior iliac spine and it is extended posteriorly just above the capsular attachment on the rim of the acetabulum. Care must be taken posteriorly to avoid extending the osteotomy through the sciatic notch. The osteotomy is carried through the outer and inner tables of the ilium; the entire roof of the acetabulum is separated and hinged forward on the triradiate cartilage. A large wedge of bone is removed from the superior portion of the crest of the ilium; this is wedged in between the acetabulum which has been turned down and the ilium. In exposing the ilium, originally the iliac epiphysis is removed with the muscles and reflected medially. Thus, the graft is removed from beneath the iliac epiphysis. The author in all instances

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but one used only the bone from the ilium for the wedge. It is his opinion that by the time the child is two years old, adequate bone substance can be obtained for the prop. In one child, eighteen months old, there was inadequate bone to hold the acetabulum down in place and the correction was lost. The author recommended that the operation should not be done in children under two, unless accessory bone is used other than from the ilium. If there is undue relaxation of the joint capsule, the capsule is tightened by taking stitches from the outer attachment of the capsule near the greater trochanter and imbricating it over against the anterior-inferior iliac spine. This is done without opening the hip joint. The patient is immobilized in a cast for two months after the operation; upon removal of the cast, the patient should be allowed to walk.

The author concluded that complications of coxa plana, limitation of motion, abduction weakness, and painful walking postoperatively were diminished below the incidence of such conditions seen in any other type of reconstruction of a congenitally dislocated hip.

Surgical Treatment of Congenital Dislocation of the Hip in Children. Prof. Wiktor Dega [51] presented a one-stage procedure for removing all the abnormalities of the dislocated hip. The most favorable age for this procedure ranges from three to five years. The operative procedure may be described briefly as follows. The hip joint is approached by the anterolateral route. The sartorius and the tensor fasciae latae are separated and the gluteal attachments are reflected from the ilium subperiosteally. A capsular arthroplasty is performed after the method of Colonna but without preoperative traction. After the head is covered with the articular capsule, the socket is deepened by means of a hand reamer. An oblique intertrochanteric osteotomy is then performed subperiosteally. This permits correction of the femoral torsion and shortening of the femur. The proximal end of the femur (the capsule-covered head, the neck, trochanters, and all muscle attachments if possible) completely free of acetabular attachment is moved downward. The blood supply is maintained through the attached glutaeus medius, glutaeus minimus, the external rotators, the periosteal tube, and the overlying muscle attachments still in continuity with the lower femoral fragment. Femoral torsion is corrected and the lower femoral fragment is shortened, overlapped, and wired. The osteotomy is modified if additional correction for coxa valga or coxa vara is required. The osteotomy is transverse at the subtrochanteric level; the distal fragment is shortened; the torsion is corrected; and the desired neck-to-shaft relationship is obtained and maintained by a Blount metal plate and screws.

Postoperatively there is immediate immobilization in a double hip spica. Sitting is permitted in the cast in the fourth week. The cast is removed and free movement is encouraged at the sixth week. Weight-bearing is permitted at the third month, although occasionally this is delayed to the sixth month. Operation on the opposite hip is done if dislocation is bilateral six months later. Three hundred and ninety-eight patients have been operated upon by this method since 1953. There were four fatalities, three of which were attributable to operative shock. Improvement in anaesthesia eliminated fatal shock during the last 208 operations. Seven redislocations occurred; after re-operation, three excellent results were obtained. Late subluxation occurred in seven and the final results in these were poor. The shaft fragment broke in two patients during the operation but the end result was not affected.

In assessing his results, four factors were taken into consideration, namely, movement, gait, pain, and fatigue. Flexion, extension, and internal rotation were the index motions for the hip. Pain, limp, and fatigue were judged by their severity and recorded numerically on a one-to-ten scale. A total of ten points was considered excellent; 8 to 9, good; 5 to 7, fair; and 5 or less, poor. Three hundred and ninety-eight hips were operated upon between 1953 and 1957 by this method. One hundred and seventy-two of these were operated upon between 1953 and 1955 and were followed two to four years. The ages ranged from three to twelve years. The age of six seems to be a border line between good and bad results: 84 per cent were excellent or good under six years of age, and 94 per cent were excellent or good between three and five years. There were only 23 per cent satisfactory results if the operation was performed after the age of six. Vascular changes were present in 28 per cent becoming evident by the sixth month and reaching the peak at the twelfth to the twenty-fourth postoperative month. When slight they persisted three to four months but when severe, these changes persisted during the entire observation period (two to four years). Vascular changes were transient in young children but were severe in older children and gave unsatisfactory clinical results.

Traumatic Dislocation of the Hip. Comparison of Open and Closed Methods of Treatment in Certain Types. Dr. Herman C. Epstein [52] presented a supplement to the paper he wrote with Dr. Vernon P. Thompson and published in The Journal in 1951 *. It is a study of fifty-four patients with posterior fracture-dislocation of the hip of various types. In thirty-six, open reduction was done, either as a primary procedure or after manipulation had failed to reduce the fracture-dislocation. The results were, in general, better than those reported previously. Early primary open reduction is indicated in the majority

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of fracture-dislocations of the hip, for there are, in many instances, small fragments of bone which are not visualized in the preoperative roentgenograms. Some of these fragments may be as small as a grain of sand. It is suggested that if the dislocation is reduced and the fragments are allowed to remain in the joint, traumatic arthritis is rapidly initiated. Removal of the fragments prior to reduction of the dislocation will minimize secondary degenerative joint changes. It is impossible to explore the joint adequately after the dislocation has been reduced except by redislocation of the joint. In such instances the advantages to be gained by removal of any occult loose bone fragments from the joint must be weighed against the effects of redislocating the hip. In the group of patients studied by the author, the majority of the patients in whom the dislocation was reduced within twenty-four hours of injury had a good result. He pointed out, however, that this does not establish as a fact that late reduction of the dislocation will necessarily fail, for a substantial percentage of those patients also had a good result.

* Thompson, V. P., and Epstein, H. C.: Traumatic Dislocation of the Hip. J. Bone and Joint Surg., **33-A**: 746-777, July 1951.

Osteitis Pubis. Dr. William J. Schnute [53] presented a series of seven cases of osteitis pubis. Six of hese were in adult females with an age distribution of from thirty-three to fifty-nine years. One case was in a male, aged forty-five. The author was not able to attribute the onset of the disease in his cases to any single cause, and stated that he could find no definite etiology. He pointed out that, with few exceptions, it is a self-limited disease lasting from a few weeks to three or more years. Treatment was primarily symptomatic, consisting in rest, support with cast or corset, physical therapy, and x-ray therapy. ACTH and cortisone were used with apparently good results.

The author described a new operation which he believes to be of value for the occasional patient in whom the symptoms are severe and prolonged and do not respond to conservative measures. This consists in wedge resection of the posterior aspect of the symphysis pubis, only the anterior cortex of the pubic bones and the anterior muscle and ligamentous attachments being left intact. The base of the wedge is approximately two centimeters from either side of the mid-line posteriorly. Three of the author's patients were operated upon by means of this procedure; in each the symptoms were completely relieved. Normal activities were resumed. In one of the patients there was slight recurrence one and one-half years later which was treated with cortisone injections into the symphysis pubis and also cortisone given by mouth.

Mobility Studies of the Lower Portion of the Lumbar Spine in Relation to Low-Back Pain. Dr. Merrill C. Mensor [54] and Dr. Gene Duvall [55] stated that their purpose was to determine the significance of motion changes in the low lumbar spine and to compare these findings with a suitable group of normal controls. They also wished to determine the etiology of extremes of motion as a possible aid to treatment. They based their findings on a series of 544 consecutive records of patients with low-back disability. The control series included ninety-four persons with no history of backache. Half of the cases were analyzed a year in advance of the other half and a comparison was made between the statistics of the two series before total evaluation. Variation in statistics between the two series was less than 5 per cent.

They described the technique of making the roentgenograms of the bending patient in the erect position. The method of measuring mobility (flexion and extension) and instability (sliding) was discussed.

They classified the cases in etiological categories: (a) sprain, (b) strains with spondylosis or disc disease or both, (c) disc herniation, (d) congenital anomalies, and (e) other lesions grouped together.

As a whole, in the patients with low-back pain, there were 42.6 per cent with immobility and 13.4 per cent with primary instability. In the control patients, on the other hand, there were immobility in 14.5 per cent and instability in only 8.5 per cent.

In the analysis of causes of pain referred to the lower extremity, they found that 68 per cent of the patients had such pain from causes other than disc herniation. Relationship of pain to injury and age was discussed.

In 36 per cent of the patients there were acute lesions and in 64 per cent, chronic lesions. The majority of patients with immobility had lesions of over two months' duration and were in the fourth to sixth decade of life. The decrease of motion found in each one of the five classifications was given as determined clinically and roentgenographically.

In summary, they stated that normal percentages must be subtracted from the percentage of abnormal findings in order to establish a base line. Thus they found an average 28 per cent absolute absence of motion in pathological conditions above the base line. They further discussed the percentage of abnormality above the base line for specific classifications. They stated that periosseous changes accounted for most of the loss of motion—not the mechanics of the bone-joint system itself. Soft-tissue shortening incidental to muscle spasm was alleged to occur. No single factor was solely responsible, however, for the changes in motion or instability.

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In their conclusions they stated that only a small percentage of normal people actually showed decreased motion in the lumbosacral region. A minor percentage of primary instability occurred and it was only this small fraction of patients so affected when sufficiently symptomatic in whom surgical arthrodesis seems indicated. Their findings cast doubt upon the necessity of frequent spine arthrodesis done after diagnosis of "unstable low back." It was stated that absence of motion is generally due to causes periosseous in origin, but other factors enter in. They suggested that the absence of motion may be used as a diagnostic finding in doubtful low-back disc syndrome and as an indication for necessity of spine fusion; when disc laceration is associated with considerable motion, fusion is indicated.

Staphylococcal Hospital Infections. Dr. Howard H. Steel[56], Dr. H. Taylor Caswell, Dr. Kenneth M. Schreck, and Dr. Norman Learner outlined a year's experience in a large general hospital with infections caused by an antibiotic-resistant strain of staphylococcus. This strain was studied by antibiotic susceptibility patterns and by phage typing. In a period of one year there 323 hospital-acquired infections. A large proportion was caused by the *Staphylococcus aureus* of the phage type 42B–52–81. During the same study period, eighty-seven patients were admitted from the out-patient department with staphylococcus infections of which 16 per cent were of the phage type 42B–52–81. In hospital personnel, eighty-four had staphylococcus infections during this study period accounting for a total of 137 infections, with 62 per cent 42B–52–81 phage type, while 640 hospital personnel were surveyed by nasal culture, with 265 positive *Staphylococcus aureus* in the nasal passages, but only eleven of these had the phage type 42B–52–81. Emphasis was placed on established medical and surgical techniques in the treatment of the infection, and control measures were outlined.

Orthopaedic Surgery in Adult Spastic Hemiplegia. Dr. Victor M. Dillon[57], Dr. Eugene N. Solovieff, and Dr. Walter J. Treanor described some of their experiences in the application of the innovations of Strayer, Eggers, Baker, and Yount to the surgical treatment of 119 adult patients affected by spastic hemiparesis.

Stressing the concepts that control of movement is a sensory-motor, rather than pure motor function, and that peripheral spasticity reflects hyperirritability and abnormal conductivity at the spinal synapse, they defined their treatment as "surgical de-afferentiation" or surgical reduction of afferent signals from some postural muscles.

Another postulate was made: that with reduction of cortical and subcortical inhibitory relays, spinal-synapse irritability is "pre-set" in a pattern favorable to phylogenetically primitive postural reflexes; in the upper extremity, flexor muscles—atavistically antigravity—dominate, and in the lower extremity, extensor or "prop" muscles dominate. This was said to explain the obvious imbalance in the rate of recovery of opposing flexor and extensor limb muscles seen clinically soon after the onset of spastic hemiparesis.

They classified treatment under two subheadings; "conduction blocks," neurectomies, or neurotripsies, and "operations on end organs," tenotomies, tendon-lengthenings, or transpositions. In either class of treatment there is expectation not only of reduced frequency of proprioceptive impulses from dominant muscles, but also facilitation of ingress of signals from previously overstretched or overpowered antagonists.

The 119 patients operated on had had adequate medical rehabilitation and were chosen for surgery from a group of 563 hemiparetic patients. The great majority of the patients were affected by cerebrovascular disease or by cerebral trauma. The estimates *success* or *failure* without gradation were used in assessing results.

In the upper extremity functional successes were achieved in 36 per cent of forty-nine patients operated upon. Among these were: reduction of reflex irritability of the finger flexors after tenotomy of the brachioradialis and palmaris longus; improvement of the adducted thumb after transfer of the flexor radialis into the abductor pollicis longus and extensor carpi radialis brevis; increase of finger extension excursion after tenodesis by transfer of the flexor carpi ulnaris into the long finger extensors.

Equivocal results were obtained in attempts to reduce flexion-pronation at the elbow by musculocutaneous neurotripsy and by neurotripsy of the median branch to the pronator teres, or by excision of the tendon insertion of this muscle. Neurotripsies of the median nerve axons to the flexor groups largely resulted in failure, and causalgia developed in some of these patients.

In the lower extremity success was obtained in 73 per cent of ninety-three patients operated upon. Treatment was designed especially to diminish circumduction of the involved leg due to delay of knee flexion in the swing phase and to improve equinovarus position of the foot in walking. For treating the former defect neurotripsies of the femoral-nerve branches to the vastus lateralis particularly were successful, demonstrating that quadriceps overactivity rather than paresis caused stiff-knee gait. Improvement of stiff-knee gait also followed rectus femoris tendon or iliotibial tract release, and in some patients, gastrocnemius tenotomy.

The Strayer method of gastrocnemius recession was described as "by far the most rewarding procedure." Tenotomy of the posterior tibial tendon, transfer of the anterior tibial tendon to the middle cunei-

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57. 2166 Hayes Street, San Francisco 17, California.

form, and transfer of the long toe extensor laterally on the foot also were successful in some patients as single procedures and in others in combination with gastrocnemius release. Posterior tibial neurotripsy was considered applicable to patients with considerable latent power in dorsiflexor muscles, but in general the reversibility of the effect of the procedure was considered a disadvantage.

Hip Arthrodesis and Poliomyelitis. Dr. Halford Hallock [58] reviewed the New York Orthopaedic Hospital and Dispensary's experience with arthrodesis of the hip for patients with extensive paralysis of the lower extremities subsequent to poliomyelitis. The purpose of the presentation was to re-affirm the findings presented before the Academy in 1950. Originally the procedure was reserved for patients with paralytic dislocation. The results were so successful that the indications were extended to include flail-hip, flail-knee, and flail-ankle on the same extremity, provided the ligaments of the knee were strong, there was no flexion contracture of the knee, the musculature of the abdomen and in particular the quadratus lumborum was functional and the foot and ankle stable or rendered so by pantalar arthrodesis. Hip fusion was performed by an intra-articular method with internal fixation. Following these operations the patients derived considerable benefit to compensate for the resultant loss of joint mobility. They became pain-free, and walked with a reduction in limp, and usually without the assistance of external support. Eight patients were shown at the meeting and they demonstrated their ability to walk, to ascend and to descend stairs, and to sit. All but one walked without a crutch, and the degree of limp in most cases was determined by the amount of residual muscle weakness in the opposite extremity.

The Pathology of Connective-Tissue Injury Following Poliomyelitis. A Comparative Biochemical Study on Fascia Lata. Dr. Philip Radding [59] believes that not only is there a neuromuscular injury in poliomyelitis but also a mesenchymal injury which accounts for fascial contractures. Although no abnormality was observed in fascial contractures by histological examination, the author believes that mesenchymal injury was demonstrated by an abnormal rise in the concentration of the ground substance early in the course of the disease followed by a fall in concentration nine months from onset. This ground substance, which consists of a highly viscid composite of mucoproteins (or mucopolysaccharides), was determined by an enzymatic extraction of carefully dessicated fascia lata. The results were compared with those from control patients, geriatric patients, and scar tissue in fascia. In both the scar tissue and in fascia lata from poliomyelitic patients early in the disease, the concentration of ground substance was elevated.

Kappa Delta Award Paper

The Effect of Total Body Irradiation on Bone Transplants in Parabiosed Animals. Dr. William F. Enneking [60] summarized the literature on parabiosis as an experimental tool with regard to transplantation experiments. He then described an experiment in which three hundred and seventy-three pairs of rats were joined, two to three days after irradiation of one member of the pair with 100 roentgens. Weekly irradiation to the irradiated member was continued throughout the course of the experiment. Three to five weeks after parabiosis, segments of the femur were exchanged between the pairs of surviving animals. Skin grafts were also interchanged. The incidence of fatal parabiotic intoxication in animals who survived ten days was 43 per cent—nearly all of which represented the irradiated member of the pair. Of the survivors, one-third of the pairs showed inflammation in the non-irradiated graft, while none occurred in the irradiated animal. In more than half of the pairs there was no inflammatory response to the transplant either in the irradiated or non-irradiated host. Three of forty-seven animals showed inflammatory responses to the graft in the irradiated animal. The results demonstrated that irradiation of a member of a parabiotic pair tends to increase its tolerance for a homogenous graft of bone from its partner, and tends to decrease the percentage of fatalities from parabiotic intoxication while confining them to the irradiated member of the pair. A significant number (60 per cent) of grafts from irradiated animals to their partners survived and healed as well as autogenous grafts.

Results in Treatment of Scoliosis with Turnbuckle Plaster-Cast Correction and Fusion. Dr. Louis A. Goldstein [61] analyzed the results in treatment of thirty-five patients with idiopathic scoliosis, twenty-one patients with paralytic scoliosis, and four with congenital scoliosis. Of these sixty patients, fifty-four had been followed for a minimum period of fourteen months after correction in a turnbuckle cast and spine fusion. Only one patient was under ten years of age when operated upon. Thirty-four were between the ages of thirteen and seventeen years.

Routine treatment included fourteen by thirty-six roentgenograms made with the patient standing, supine, and bending to the right and left. The curves were measured in the manner described by Cobb. The allowable correction was determined from the roentgenograms made with the patient bending and the

58. 180 Fort Washington Avenue, New York 32, N. Y.
59. 600 Asylum Avenue, Hartford, Connecticut.
60. University of Mississippi Medical Center, Jackson, Mississippi.
61. 15 Prince Street, Rochester 7, New York.

angulation of the primary curves was not corrected beyond the sum of the correctable angles of the compensatory curves. In general only the portion of the spine involved in the primary curve was fused.

The turnbuckle corrective cast included the head and both thighs.

Fusion was done through a wide window, permitting removal of iliac bone for autogenous-bone graft material. The important points in the fusion technique were: (1) a straight incision, (2) exposure carried beyond the joints and transverse processes, (3) meticulous removal of soft tissue, (4) creation of bone flaps of full cortical depth with a very sharp hand gouge, the use of a mallet being avoided. Flaps were taken from transverse processes, laminae, and spinous processes and were laid across the interlaminar space.

Tibial osteoperiosteal-bone grafts were added from 1939 through 1947. Bone-bank bone chips were used from 1948 through 1951. Iliac autogenous-bone grafts were used since 1952.

Postoperatively, the full cast was left on for six months. Then a bent cast which includes one thigh and a single shoulder strap is applied. The patients were allowed to walk in a bent body cast at eight months after fusion. All support was removed at ten months after fusion.

There were seven pseudarthroses in the fifty-four patients (13 per cent) followed.

In thirty-one patients with idiopathic scoliosis there were three pseudarthroses; in twenty-one patients with paralytic scoliosis there were two pseudarthroses.

In twenty-five patients with idiopathic and paralytic scoliosis in whom fresh autogenous iliac bone was used pseudarthroses occurred in one patient (4 per cent).

In twenty-six patients in whom other types of graft material were used pseudarthroses occurred in four (15.4 per cent).

The degree of curvature in 75 per cent of the patients was over 70.

The patients were divided into Group I (those in whom all other types of graft material were used) and Group II (those in whom fresh autogenous iliac bone was used).

In Group I (twenty-six patients) the curves varied from 42 to 148 degrees. There were sixteen patients with curves of over 70 degrees. There were fifteen patients in whom the correction was from 60 to 89 per cent. Nine patients showed from 39 to 69 per cent gain, and in two patients the gain was over 90 per cent.

The loss of correction varied from 10 per cent (three patients) to 57 per cent (one patient) and 92 per cent (one patient). Ten patients lost from 22 to 41 per cent of correction.

Pseudarthrosis caused loss of correction of 29 per cent, 50 per cent, 100 per cent, and 89 per cent in four patients.

In Group II (twenty-five patients), the curves varied from 63 to 122 degrees. Twenty-two patients had curves of over 70 degrees.

The gain in correction was from 50 to 79 per cent in sixteen patients, and was from 40 to 49 per cent in five patients, and 80 to 89 per cent in four.

Loss of correction was 10 per cent in sixteen patients, 11 to 21 per cent in seven, and 55 per cent in one. One pseudarthrosis resulted in a 26 per cent loss of correction.

No graft fractures or delayed pseudarthrosis were observed. Loss of correction after the first postoperative year was insignificant in the presence of solid fusion.

There were no deaths. Three postoperative infections occurred, causing one pseudarthrosis. Brachial plexus pressure from the cast occurred in two patients.

The author concluded that fresh autogenous bone used in conjunction with his method of correction and fusion gave a low incidence of pseudarthrosis and solid and mature fusion in one year after operation.

Structural Changes in the Lumbosacral Spine Following Lumbosacral Fusion. Dr. Everett C. Bragg [62], Dr. Daniel Winters, and Dr. Duke Baird reported on 200 patients who had had lumbosacral fusion. The fusion area was investigated as regards strain or other changes occurring above the fusion area in the lumbosacral spine. Of these, 100 operations had been done for disc disease and 100 operations had been done for "unstable lumbosacral spine."

The results were classified as regards occupation, symptoms, and medical status. Satisfactory results in the patients with disc disease were obtained in 91 per cent, and in those with the unstable backs in 89 per cent.

Residual symptoms occurred in 40 per cent more of the patients with disc disease than in those with unstable backs. In the total series forty-nine pseudarthroses developed; sixteen of these were repaired.

There was thinning above the fusion area in forty-nine of the 200 patients. Osteo-arthritic changes occurred above the level of fusion in 50 per cent of the patients. The authors judged that the majority of these changes had become established before fusion was done. Abnormality of motion above the fusion area was not considered to be of importance. Disc herniation above the fusion area occurred twice in the 200 patients, once in a patient with previous disc herniation and once in a patient with an unstable back. Both of these herniations were located at the third lumbar segment and were degenerated discs without protrusion or demonstrable root pressure.

62. 654 Madison Avenue, New York 62, N. Y.

In two of the patients the fusion area was extended one segment above the previous fusion area for symptoms of instability and in both of these instances such fusion was done at the fourth lumbar interval. Of the twenty-five patients re-operated upon, one patient was found to have compression by the fusion mass as well as anterior compression.

Results were better in the patient with disc disease in whom fusion had only been done at the lumbosacral joint, and in the patients with unstable lumbosacral spine in whom fusion had been done at the fourth lumbar segment. They concluded that lumbosacral fusion did not result in significant adverse structural changes in the lumbosacral spine.

Femoral Torsion and Its Relation to Toe-In and Toe-Out. Dr. Lawrence Crane [63] reported that the normal anteversion of a group of school children was measured from roentgenograms made with the child held in a frame with the hips at 90 degrees of flexion and 30 degrees of abduction. In conjunction with an anteroposterior roentgenogram, the angle of anteversion was calculated from a previously compiled table. Anteversion was 40 degrees at six months of age and declined to 25 degrees at the age of five years.

It was shown that, on the average, youngsters who walked with a toe-in gait had femoral anteversion above the normal as measured by this method. Those who walked with a toe-out gait had, on the average, a decreased amount of femoral anteversion.

A night splint to control rotation while the child was sleeping was used in those children in whom the degree of femoral anteversion appeared to be a factor in the faulty gait.

Anteversion of the Femoral Neck. A Right-Angle Triangle Method of Determination. Dr. T. Gordon Reynolds [64] and Dr. Fred E. Herzer [65] described a simple method to determine by routine anteroposterior and frog-leg roentgenograms, anteversion, or torsion of the femur. In the frog-leg view, the knees must be flexed to a right angle and the tibiae supported horizontally. For the anteroposterior roentgenogram, the femora must be in the anatomical position. Anteversion was determined by measuring on these roentgenograms the lateral and posterior displacement of the femoral shaft relative to the femoral head.

The procedure was described as follows:

1. The distance *a* from the center of the head to the axis of the femoral shaft was measured on a frog-lateral projection.

2. The distance *b* from the extended axis of the femur to the center of the head is measured in the anteroposterior roentgenogram.

3. A right-angle triangle is drawn with the altitude and base proportional to *a* and *b*. Angle *A*, which is opposite the altitude side *a*, is the angle of anteversion or torsion of the femur.

If instead of drawing a triangle a slide rule is used, the formula TAN $A = \frac{a}{b}$ may be used. Here also *a* is the posterior displacement and *b* the lateral displacement.

If the cervicofemoral angle is about the same in each view, that is, if the head is about the same distance from the axis of the femur in each roentgenogram, there is about 45 degrees of anteversion. If the anteroposterior roentgenogram shows apparent valgus and the frog-leg lateral roentgenogram shows considerable anterior angulation of the femoral neck, there is moderate to severe anteversion. If the posterior displacement of the shaft shown on the lateral roentgenogram appears less than the lateral displacement on the anteroposterior roentgenogram, anteversion is probably normal. One case of a girl with pigeon toes and moderate anteversion was reported. It was stated that the probable cause of pigeon toes is anteversion. The advantages of this method are described as being twofold: (1) the amount of anteversion can be roughly estimated by a glance at the roentgenograms or can be measured by a simple projection drawing, and (2) additional radiation exposure is not necessary to determine anteversion.

Combined Triple Arthrodesis and Posterior Bone Block in Paralytic Foot-Drop. Dr. M. Melvin Clark [66] reported on the end results of a combined triple arthrodesis and posterior bone block on twenty-three feet in twenty patients. In the author's hands the combination of triple arthrodesis and Gill posterior bone block were done with greater speed and ease than most tendon transplantations or the Lambrinudi type of stabilization. He said that there is greater stability with little chance of fracture in this bone block as compared with the Campbell type of posterior bone block and there is more natural gait when some ankle motion remains. Calcaneus deformity did not follow the procedure. Some return of power in the extensors of the foot in a few cases was observed. It was recommended that the triple arthrodesis be done first through a lateral incision followed by the Gill posterior bone block done through a vertical incision parallel to the heel cord on its lateral side. The tendon is divided in Z fashion. The posterior portion of the articular surface of the talus is raised and a bone wedge taken from the dorsum of the tuberosity of the calcaneus is inserted. Healing was reported as occurring from twelve to sixteen weeks in plaster. At the time of surgery the ages of

63. 265 Western Promenade, Portland 4, Maine.
64. 1700 Brooklyn Avenue, Los Angeles 33, California.
65. White Memorial Hospital, 1720 Brooklyn Avenue, Los Angeles 33, California.
66. 38 Goodman Street North, Rochester 7, New York.

patients ranged from nine to forty years, the average being twenty years. There were seven males and thirteen females. Follow-up was from two to twelve and one-half years. Criteria of end results were a solid fusion in good position, a painless foot, the block holding well, and satisfaction of the patient.

Of the twenty-three feet, seventeen were rated *excellent*; two, *very good*; one was graded down because of slight varus deformity; the other was graded down because of slight discomfort. Three were rated *good*; two because of some increase in foot-drop and one because of failure of bone fusion at the talonavicular joint. In only one patient did failure result. In this patient the block was inadequate and plantar flexion recurred.

Viewpoints in Treatment of Congenital Dislocation of the Hip in Infancy. Dr. Joseph Milgram [67] discussed his experience in the management of congenital dislocation of the hip in infancy. He emphasized that treatment in early infancy is advisable but that it is not without danger. He stressed the fact that manipulative reduction often damages the femoral heads in these young infants and true manipulation should not be used. He advised closed reduction by simple abduction or traction methods and if these proved unsuccessful, open reduction is advised. For abduction, he uses a foam rubber pad folded into a diaper as a pillow splint, and advised against forced and excessive abduction by rigid appliances. For traction he utilizes principally the traction cast but states its use should be limited to patients with unilateral involvement.

Anteversion at times has proved to be a problem in the maintenance of reduction but in infants it has generally corrected spontaneously within the year.

In a series of 139 cases, with 159 hips involved, he reported very poor results in the group treated by manipulation under anaesthesia and a "large preponderance of good results" in the group treated by abduction and traction method. Of forty-two hips treated by manipulation under anaesthesia, the results in twenty-nine were classified *bad*. Of a combined total of ninety-seven hips treated by abduction or traction methods, the results in seventy-nine were classified *good*.

Flexion-Adduction-Internal Rotation Deformity of the Hip in Cerebral Palsy. Dr. William T. Green [68] and Dr. Henry H. Banks [69].

Giant-Cell Fibroma of Bone. Dr. J. Vernon Luck [70] and Dr. Weldon K. Bullock [71] called attention to the confusion that still exists in the realm of giant-cell tumors. They described an entity which they have termed *giant-cell fibroma of bone*. The clinical feature of this lesion is a wide distribution in the long, flat, and small bones with the most frequent site in the metaphysis of the long bones. Pain is not an outstanding symptom. The lesion occurs most commonly in the second decade of life and is evenly divided between males and females. It occurs as a solitary lesion.

The histological characteristic of this lesion is a fibrogenic stroma with a prominent collagen component. The giant cells vary in number and size and tend to be smaller than the giant cells of the giant-cell tumor. They contrasted this lesion with giant-cell tumor by stating that the tumor tissue does not consistently destroy bone and is frequently seen around foci of osteoid. Another distinguishing feature of this lesion is the appearance of thick-walled blood vessels with well defined muscular walls.

This lesion according to the authors is closely related to the aneurysmal bone cyst and it is their conviction that an aneurysmal bone cyst represents a giant-cell fibroma in which a pseudo-aneurysmal component has developed. They also stated that they believe the lesion described to be identical with the lesion of the jaw described by Jaffe and termed *giant-cell reparative granuloma*.

They believe that the proper treatment of this lesion is excision and bone-grafting. When surgical excision is not feasible, roentgen therapy will be found effective. No malignant transformation of this lesion was observed in twelve cases.

Hemangioma of the Synovium. Dr. Royce C. Lewis, Jr., Dr. Mark B. Coventry [72], and Dr. E. H. Soule.

Fibrous Dysplasia of Bone. Dr. Marcus J. Stewart [73], Dr. W. Scott Gilmer, Jr.[74], and Dr. Allen S. Edmonson [75] presented a review of seventeen patients with fibrous dysplasia of bone seen at the Campbell Clinic during the past thirty years. Of the seventeen cases, thirteen were in male and four were in female

67. 1919 Madison Avenue, New York 35, N. Y.
68. 300 Longwood Avenue, Boston 15, Massachusetts.
69. 300 Longwood Avenue, Boston 15, Massachusetts.
70. 2400 South Flower Street, Los Angeles 7, California.
71. Department of Surgical Pathology, Los Angeles County Hospital, Los Angeles, California.
72. Mayo Clinic, Rochester, Minnesota.
73. Campbell Clinic, Memphis, Tennessee.
74. Campbell Clinic, Memphis, Tennessee.
75. Campbell Clinic, Memphis, Tennessee.

patients. Only two patients were over twenty-one years of age when first seen. Excluding these, the average age at the time of onset of symptoms was nine years, with a range from one to sixteen years. Pain, deformity, and pathological fractures were the presenting symptoms. One case was polyostotic with all the manifestations of Albright's syndrome, two were monomelic which the authors described as that group in which there is more than one focus in the same extremity, and fourteen were monostotic. In none of their monostotic cases was there any pigmentation of the skin or sexual precocity.

The roentgenogram showed an expansion of the bone with erosion and thinning of the cortex. Areas of rarefaction were not surrounded by a zone of sclerosis. A multilocular appearance was often noted. Although the roentgenogram was characteristic in polyostotic cases, it was not found to be conclusive in the monostotic lesion.

On the basis of the histological changes noted in the seventeen patients, the authors postulated that the fibrous dysplastic process undergoes an evolutionary change. They stated that originally it is highly cellular with relatively little bone formation and that as it reaches an adult phase, the bone production becomes marked. As the lesion ages the cellularity becomes less pronounced and bone formation ceases.

The authors obtained excellent results in monostotic fibrous dysplasia by thorough curettage and packing with bone grafts. In polyostotic and extensively involved monomelic cases, emphasis was placed on correction of deformity rather than ablation of the tumor. Osteotomies healed without difficulty. Radiation therapy was of little or no value.

The authors believe that fibrous dysplasia is basically a developmental defect originating in the embryo or early infancy.

SCIENTIFIC EXHIBITS

Non-Malignant Segmental Vertebral Sclerosis Simulating Neoplasm. Dr. Wolfgang Ackermann [1] and Dr. Gerhart S. Schwarz [2] presented the results of an extensive histological and roentgenographic study of vertebral bodies to demonstrate a non-malignant, but neoplasm-simulating, variety of osteosclerosis never before reported. Of 340 biopsy specimens taken from patients in whom the diagnosis was cancer, twenty-eight showed sclerosis histologically. Among these were thirteen non-malignant cases; in seventeen of the twenty-eight the diagnosis had been made roentgenographically. In only five of these was neoplasia not found. Thus about 4 per cent of the patients had histologically proved non-malignant vertebral sclerosis, while in only 1.5 per cent was there roentgenographic evidence of segmental vertebral sclerosis, which was proved microscopically to be non-malignant.

From this study was evolved a concept of benign vertebral sclerosis, particularly since autopsies of three of the patients in the series revealed that the vertebral bodies were free of cancer cells. Therefore it was concluded that osteosclerotic changes did not represent osteoblastic metastases. In addition, in both of the patients whose cases were illustrated and who had been followed for two and thirteen and one-half years, respectively, there had been no change.

The exhibited material demonstrated the characteristic features of this benign sclerosis of vertebral bodies in contradistinction to other known benign types of osteosclerosis. The discogenic type of osteosclerosis was eliminated since it was shown in the exhibit that the adjacent intervertebral discs were not involved either histologically or roentgenographically. Bone islands, which have ovoid configurations and are not segmental as seen roentgenographically, were not investigated histologically. There was neither clinical nor histological evidence of bone infarct, ischaemic necrosis, infection, or osteoma. Paget's disease, as well as osteopetrosis and osteopoikilosis, were not considered because, in addition to other distinct characteristics, they involve numerous bones.

The sole histological feature of the lesions described and demonstrated at the exhibit was a marked increase in the bone elements obliterating and displacing the marrow spaces. It was demonstrated that roentgenographically an entire segment of the body of a vertebra in its full thickness was involved. It was also stressed in the case histories that these lesions were single, that they occurred in patients over thirty years of age, and that they appeared not only in people with cancer, but also in normal individuals. They rarely produced symptoms; obviously they were incidental findings.

Illustrative material of a case of Schmorl's discogenic vertebral sclerosis and statistical diagrams analyzing trephine vertebral biopsies in 340 patients were included. A set of Ackermann instruments, used successfully in these biopsies, was also displayed.

It was concluded that non-malignant segmental vertebral sclerosis is usually indistinguishable from

1. 240 Central Park, South, New York, N. Y.
2. 622 West 168th Street, New York 32, N. Y.

osteoblastic solitary metastases roentgenographically and that the incidence of non-malignant sclerosis may be even higher in patients in whom no cancer is clinically suspected.

Whenever roentgenograms indicate the presence of solitary osteoblastic vertebral metastasis, a vertebral trephine biopsy was strongly recommended since, of the seventeen segmental sclerotic lesions demonstrated, five were found not to be metastatic.

American Board for Certification of the Prosthetic and Orthopedic Appliance Industry, Inc. MR. LESTER A. SMITH [3] presented a review of the Certification Board program and the Academy's role in its work processes. Since 1958 marks the beginning of the second decade of the Certification movement, the display described this role through the years.

The Board was incorporated as a non-profit venture in the state of Delaware in 1948. Three of the seven members of the Board are orthopaedic surgeons selected from the membership of The American Academy of Orthopaedic Surgeons. This arrangement is now formalized so that each year the Executive Committee of the Academy nominates the orthopaedic surgeon who is to serve a three-year term. Three other members of the Board are prosthetists or orthotists nominated by the trade association, the Orthopedic Appliance and Limb Manufacturers Association. The seventh member of the Board is a certified orthopaedic technician, nominated by an advisory council representing the 1,100 men certified as orthopaedic ... prosthetic appliance technicians.

In the years since the Board was established, the surgeon members have taken an active role in its deliberations. Two surgeons served as President of the Board: Dr. Roy M. Hoover, of Roanoke, Virginia, President for the year 1957–1958, and Dr. Robert Mazet of Los Angeles, President 1955–1956. Surgeons who have served as Vice Presidents of the Board include Dr. Atha Thomas, of Denver, Dr. T. Campbell Thompson, of New York City, and Dr. Edward C. Holscher, of St. Louis.

The purpose of the Board, a non-profit organization, is to "establish standards for those engaged in the fitting of prosthetic or orthopaedic appliances, particularly with respect to the adequacy and cleanliness of facilities and proficiency and honesty in service rendered, and with the object of discouraging the practice of this profession by technically unqualified persons." The Board relies largely on the judgment of orthopaedic surgeons and other physicians in deciding which persons and which facilities are to be certified. Photographs and literature described the role of the physician in the certification procedure:

1. The technician must have had four years of experience under supervision and must have been recommended by three or more physicians, one of whom must be an orthopaedic surgeon. After passing a comprehensive written and practical examination, he takes an oral examination conducted by a committee of interviewers, including one or more orthopaedic surgeons.

2. In the certification of the facility (the firm, shop, or laboratory), where the patient is fitted and the appliance manufactured, the opinion of three or more orthopaedic surgeons who have experience with the facility is obtained.

The exhibit called attention to the continuing importance of the individual physician in maintaining and improving standards by: (1) reporting promptly to the Board's headquarters in Washington, D. C. when satisfactory service is not provided; and (2) encouraging technicians to become certified.

Also on display were the reference tools in this field of use to the physician: (1) the *Official Registry of Certified Prosthetic and Orthopedic Appliance Facilities* mailed annually to members of the Academy and other specialists interested in this field; (2) the *Official Registry of Certified Orthotists and Prosthetists* (1,100 individuals); and (3) the *Orthopedic and Prosthetic Appliance Journal*, a joint publication of the American Board for Certification and the Orthopedic Appliance and Limb Manufacturers Association.

Combined Procedure for the Repair of Recurrent Dislocation of the Shoulder. DR. CARL E. BADGLEY [4] and DR. GERALD A. O'CONNOR [5] presented a technique combining the best features of the Putti-Platt, the Nicola, and the Magnuson-Stack procedures for the repair of recurrent anterior dislocation of the shoulder. This is a simplification of all three procedures because of the excellent exposure obtained by splitting the subscapularis tendon and capsule from its insertion to well past the glenoid rim. The distal end of the subscapularis is detached from the lesser tubercle of the humerus and the proximal half is cut one inch from the insertion on the tubercle. Reflection of the two medial portions demonstrates the entire anterior glenoid rim and the biceps brachii tendon. One-quarter inch below the anterior glenoid rim an osteotome cut is made wedging anteriorly. It was said to be relatively simple to drill several holes through this bone flap and fix with silk ligatures the proximal outer one-half of the capsule and tendon of the subscapularis. The sutures pass through the soft tissue anterior to the glenoid cavity and draw the subscapularis deeply into the freshly cut bone, also serving to widen or deepen the glenoid cavity. The medial portion of this proximal half of the subscapularis is sutured to the distal half. The distal half is utilized as in the Magnuson-Stack procedure. The Nicola technique was easily accomplished between these two procedures.

3. 1145 Nineteenth Street, N.W., Washington 6, D. C.
4. 1313 East Ann Street, Ann Arbor, Michigan.
5. 1313 East Ann Street, Ann Arbor, Michigan.

It was felt that this combination provides a firm buttress to the anterior aspect of the shoulder, limits external rotation, and prevents inferior displacement.

The exhibit consisted of colored anatomical drawings illustrating the technique, transparencies illustrating the operative procedure on a cadaver, details of end-result studies, and photographs illustrating the postoperative range of motion. Ten postoperative photographs revealed that these patients had an excellent range of motion with the exception of limitation of external rotation in varying degrees.

There were fifty-nine combined operations on fifty-seven patients (two patients had bilateral repairs). In eighteen operations, the Nicola procedure was not done and there was no significant difference in the end results. There were no recurrences. Thirty-four patients were followed for from two to seven years.

It was stressed that the great majority of these patients showed the fibroelastic diathesis, and it was felt that this is an etiological factor in recurrent dislocation of the shoulder.

It was noted that this combination of repairs might be more successful in preventing recurrences in that group of patients, such as those with epilepsy and athletes who sustain severe trauma, than the single repairs.

Six patients in this group had a convulsive disorder and twenty-three patients returned to active athletic activities following operative repair.

Cathode-Ray Sterilized Cadaver-Bone Grafts. Dr. C. Andrew L. Bassett [6] and Dr. A. Gibson Packard, Jr.[7] presented a method of utilizing fresh cadavera to provide adequate supplies of bone for bone banks. Despite the wide availability of cadaver bone, relatively little is used because of the difficulties imposed by aseptic procurement techniques. Development of sterile room facilities for graft collection is rarely practical. Bone removed aseptically in the autopsy room is usually contaminated by air-borne bacteria. Therefore, to make the cadaver an effective source of bone, methods for dealing with contamination have been applied. In the past, autoclaved or merthiolate-sterilized bone has often proved inferior as a graft. Accordingly, the search has continued for a technique which will sterilize without altering the graft's biological effectiveness. Several promising experimental methods utilizing cathode irradiation, cobalt-60, and beta-propiolactone have been developed recently. The exhibit presented clinical experience with cathode-irradiated bone.

Bone procured from selected cadavera with no aseptic precautions was packaged, frozen, and irradiated with the Massachusetts Institute of Technology Van de Graaff generator. Despite the wide bacterial spectrum before irradiation no cultures were positive following irradiation. In three years, 1,759 grafts were used in 1,037 patients. The wound infection rate, 0.9 per cent, was substantially lower than that reported by others using non-irradiated bone-bank bone.

Fifty-one patients followed eighteen months or longer had histological or roentgenographic evidence, or both, of bone-graft incorporation progress. Of these, 85 per cent had successful clinical results (eight failures were not attributable to graft failure). There was one graft failure. Of 100 consecutive spine fusions (single to multiple segments in patients followed two years or more) 83 per cent were successful.

It was concluded that cathode irradiation is an effective method for sterilizing bone. In addition, cathode-ray sterilized bone is incorporated by the host in a manner and rate comparable to the best non-irradiated frozen and freeze-dried bone.

Fractures in the Aged. Dr. Edgar M. Bick [8], Dr. Alexander Garcia [9], and Dr. Thomas J. Dring [10] presented material illustrating the observations gathered in a study of the distribution and general management of fractures in the aged, based on 500 unselected cases in patients over sixty years of age.

An Analysis of 10,768 Fresh Fractures in Private Practice, 1937 to 1956. Dr. Louis W. Breck [11], Dr. W. Compere Basom [12], Dr. Morton H. Leonard [13], and Dr. John E. Emmett [14] presented a statistical analysis by means of large pictorial skeletons relating the fractures to the anatomical area of occurrence. The fractures were analyzed in detail and also by combining fractures according to area so that there was comparison by three large anatomical groups. For this purpose the fractures were divided into those of the spine and trunk, those of the upper extremities, and those involving the lower extremities.

Illuminated transparencies showed the ten fractures most common in the exhibitors' experience. There was further statistical detail concerning the number of compound fractures, the number of fractures operated upon, the operative mortality, and a comparison of the relative frequency of compound fractures according to anatomical area.

6. 180 Fort Washington Avenue, New York 32, N. Y.
7. 622 West 168th Street, New York 32, N. Y.
8. 30 East 60th Street, New York 22, N. Y.
9. 5 Terrace Drive, Port Washington, New York.
10. 111 East 61st Street, New York 21, N. Y.
11. 520 Montana Street, El Paso, Texas.
12. 520 Montana Street, El Paso, Texas.
13. 520 Montana Street, El Paso, Texas.
14. 520 Montana Street, El Paso, Texas.

The Electromyographic Evaluation of Tendon Transplants. Dr. Walter L. Butterfield [15] and Dr. Melvin R. Krohn [16] presented representative electromyographic records of patients in whom sixty-nine tendon transplantations in the lower extremities had been performed. Patients were followed for between one and twenty years after transplantation. Electromyographic records were made of the foot performing all possible active motions, as well as with the patient walking. Needle electrodes inserted directly into the muscle belly were used. The stance and swing phases of gait were indicated directly on the electromyogram.

It was found that many muscle transplants appeared to work well under voluntary control but did not function efficiently during walking. Of twenty-two transplants of the peronaeus longus to the dorsum of the foot, only three actually showed retraining of phase activity so that the normally stance-phase peronaeus longus converted to a swing-phase muscle after transplantation. In eight patients the transplants had good voluntary use and strength and the results could be rated clinically as *good* but there was little or no retraining of the muscle during normal walking when the patient's attention was not directed to the foot. Half of the results were clinical failures.

It appeared that the tibialis anterior, when transplanted to the heel, retrained its phase activity readily. In two of the three patients studied the transplant worked in the stance phase of gait, showing excellent retraining.

Transplants of the peronaeus longus to the calcaneus, tibialis anterior to the lateral side of the foot, and extensor hallucis longus to the first metatarsal were also studied. These transplants do not require a change of phase activity after transplantation, and in most cases the transplant continued to work effectively. Occasionally the transplant was found to be contracting continuously throughout gait with no phase variation; occasionally a muscle did not contract at all during walking but yet it worked well with voluntary motion against resistance.

It was felt that better methods of postoperative training are needed to convert the well established reflex pattern of contraction to a new reflex pattern after transplantation when a muscle becomes an antagonist to its normal function in gait.

Historical Volumes of the Medical Department, United States Army, World War II. Col. John Boyd Coates, Jr. [17], M.C., U.S.A. presented an exhibit for the United States Army divided into three panels.

The left panel consisted of a series of color transparencies illustrating the types of bone and joint injuries in World War II which required treatment by the orthopaedic surgeon. The center panel listed the volumes published to date in the planned fifty-volume series. The right panel, besides showing facsimile pages from the volumes, exhibited abstracts from medical-journal reviews.

Copies of the volumes were available for perusal, with descriptive literature. These books on medicomilitary history are available from the Superintendent of Documents, Government Printing Office.

Multiple Neurofibromatosis and Scoliosis. Dr. John R. Cobb [18] and Dr. Philip D. Wilson, Jr. [19].

Analysis and Management of Para-Osteoarthropathy in Neurological Disease. Dr. L. J. Cordrey [20] and Dr. J. H. Christie [21] presented an exhibit composed of four panels. One panel was devoted to demonstration by graphs of the clinical evaluation and analysis of the incidence of para-osteoarthropathy in a group of 103 patients with neurological disease. Also demonstrated were the age range of patients, duration of the neurological disease, and state of ambulation of the subjects. The roentgenographic appearance of the condition in hemiplegic patients and the end results of subtrochanteric osteotomy and bracing were shown as were the progression of ossification about the hips in paraplegic patients and the stimulation of ossification by intra-articular intervention as seen roentgenographically. Photomicrographs of biopsy specimens removed at the time of surgical intervention were employed to demonstrate marked osteoblastic activity with eventual formation of mature bone. The preoperative roentgenographic appearance of the condition in patients with multiple sclerosis and the end result of subtrochanteric osteotomy were shown.

One hundred and three patients with neurological disease were studied over a period of three years. The group was composed of fifty-four patients with hemiplegia, twenty-four with paraplegia, and twenty-five patients with multiple sclerosis. Para-osteoarthropathy was found in 22.6 per cent of those with hemiplegia, 24 per cent of those with multiple sclerosis, and in 66 per cent of those with paraplegia. In the latter two groups, the involvement of the hips was bilateral and in the hemiplegic patients was unilateral, on the paralyzed side. Age and sex were found to be of no significance. Duration of the neurological disease ranged

15. 85 Jefferson Street, Hartford 14, Connecticut.
16. 10515 Carnegie Avenue, Cleveland 6, Ohio.
17. Walter Reed Army Medical Center, Washington, D. C.
18. 333 East 43rd Street, New York 17, N. Y.
19. 535 East 70th Street, New York 21, N. Y.
20. 2073 Abington Road, Cleveland 6, Ohio.
21. 10515 Carnegie Avenue, Cleveland 6, Ohio.

from three months to thirty-two years. The ossification was noted to be progressive in character, ultimately resulting in extra-articular bone ankylosis. The joint space was preserved; the area of ossification extended from the anterior-inferior iliac spine to the base of the femoral neck and lay anterior to the hip within and directly adjacent to the joint capsule. On exploration of hips with periarticular ossification, no invasion of muscle was noted; microscopic study of biopsy material demonstrated marked osteoblastic activity and, in the firmly ankylosed hips, mature bone. Intra-articular or periarticular operative intervention in hips which manifested ossification invariably resulted in recurrence or progression of new-bone formation. For this reason, when ankylosis in malposition had occurred, subtrochanteric osteotomy and correction of the deformity was advised. No definite etiology for the ossification was determined by this study.

Diaphyseal Lesions. The Committee on Pathology, The American Academy of Orthopaedic Surgeons, presented an instructive exhibit showing the difficulty sometimes encountered in diagnosing tumors and infections in the diaphysis of the tubular long bone. The pertinent clinical history, roentgenogram, and photomicrograph were presented with the diagnosis in a concealed cupboard.

The cases included were:

1. Osteoid-osteoma of the tibia with a well defined nidus surrounded by a reactive sclerosis in the adjoining bone.
2. Ewing's sarcoma of the femur with only a small focus of radiolucency in the diaphysis.
3. Chondrosarcoma of the femur which strongly suggested the malignant transformation of an enchondroma.
4. Eosinophilic granuloma of the femur showing a marked onion-peel periosteal new-bone formation. This illustrated the non-specificity of periosteal new-bone formation.
5. Eosinophilic granuloma of the femur with a large loculated lesion surrounded by sclerotic reactive new bone.
6. Metastatic carcinoma from the kidney in the femur of a woman fifty years of age. A good result was obtained for two years following the insertion of an intramedullary nail and roentgen therapy.
7. Osteogenic sarcoma of the humerus in which the diagnosis was not made until two years following the healing of a pathological fracture. Most of the intracellular matrix consisted of osteoid so that in the roentgenogram the tumor appeared osteolytic.
8. Reticulum-cell sarcoma of the femur. Excellent healing of the fracture occurred after roentgen therapy. No evidence of tumor was found eighteen months later when a complete postmortem study followed death from a coronary occlusion.
9. Fibrosarcoma of the humerus.
10. Metastatic carcinoma from the breast. There was marked ossification within the tumor; growth of the metastatic lesion was arrested following roentgen therapy.
11. Tuberculosis of the tibia.
12. Enchondroma of the radius. There were small foci of ossification and calcification within a well demarcated tumor.

The Hands in Arthritis and Related Conditions. Dr. Alan R. Crain [22] and Dr. Milton C. Cobey [23] presented an exhibit stressing the examination of the hands in the diagnosis of rheumatic and related diseases. The exhibit illustrated the various rheumatic diseases affecting the hand and how differential diagnosis can often be made from these members alone. Fourteen *moulages* of the hand were presented, illustrating a normal hand, four different stages of rheumatoid arthritis, two of osteo-arthritis, and one of acute rheumatoid arthritis in a hand previously affected by osteo-arthritis. In addition there were hand *moulages* presenting early and late scleroderma, shoulder-hand syndrome, a psoriatic arthritis, and one of gout. Accompanying each hand was a roentgenogram and a Kodachrome photomicrograph enlargement showing the pathological changes in each case. Diagrammatic charts illustrated the pathological condition of the bone in rheumatoid arthritis and osteo-arthritis.

Changes in the Knee Joint Following Experimental Patellectomy. Dr. Anthony F. DePalma [24] and Dr. Blackwell Sawyer, Jr.[25] presented a series of joints of dogs upon which partial and total patellectomy were performed divided into three groups: those in which partial patellectomy was performed in the sagittal plane; those with partial patellectomy in the horizontal plane; and those in which the entire patella was removed.

It was noted that increasingly severe degenerative changes occurred in all three groups. The most severe alterations were noted in those joints in which partial patellectomy had been performed in the sagittal plane and in those in which the entire patella was removed.

22. 1801 Eye Street, N.W., Washington 6, D. C.
23. 1726 Eye Street, N.W., Washington 6, D. C.
24. 248 South 21st Street, Philadelphia 3, Pennsylvania.
25. Jefferson Hospital, Philadelphia 7, Pennsylvania.

It became apparent that in dogs any disturbance in the quadriceps mechanism due to excision of a portion or the entire patella eventually led to changes paralleling degenerative arthritis. The changes were least pronounced in those joints in which either the superior or inferior pole of the patella was left *in situ*.

Cervical Fracture of the Hip. Internal Fixation for Continuous Contact Compression. Dr. William Minor Deyerle [26] presented a new plate that acts as a guide for the accurate placement of multiple fixation pins. The one-half-inch center hole also guides accurate placement of the one-half-inch cancellous-bone graft parallel to the pins and well into the femoral head. This graft may be done as a primary or secondary procedure. The center hole may also be used for a sliding Smith-Petersen nail.

The pins are threaded only in the portion that engages the femoral head and may slide freely in the distal portion of the cortex and attached plate. This allows the fixation pins to be drilled to the articular cortex. If any shortening takes place at the fracture site the pins will slide distally in the plate while maintaining fixation of the femoral head at a preselected angle, usually 140 degrees. The plate is fixed to the shaft of the femur, but the fixation pins and Smith-Petersen nail (when used) slide to allow for continuous contact compression of the fracture surfaces. Five one-eighth-inch fixation pins inserted in the head maintain the valgus reduction even with immediate walking.

The principles of absolute immobilization and contact compression stimulate early union by preventing any shearing or twisting motion at the fracture site. This assures maximum protection for any blood vessels attempting to grow across the fracture into the femoral head. The absence of this fixation notoriously destroys newly formed blood vessels and creates bad future blood vessels by laying down a plaque of scar tissue. This delays union, increases the chances of non-union, and may prevent a sufficient amount of blood vessels from crossing the fracture to maintain viability of the femoral head. Aseptic necrosis is vascular failure of the femoral head. Since the plate is also a guide, a graft may be inserted at the earliest sign of trouble. This does not disturb the progress of union, and there is no loss of fixation. The entire grafting procedure using cancellous iliac bone grafts takes less than forty-five minutes.

The Artificial-Limb Program in the United States. Dr. Harold W. Glattly [27] described, in the exhibit of the Prosthetics Research Board, the organizational structure of this unique, cooperative program, and illustrated the painstaking efforts that are put forth to develop new and improved prosthetic devices, to evolve better techniques of fitting and training the individual amputee in the use of a prosthesis, and to disseminate the new knowledge to the members of practicing clinical teams. Photographs and models depicting the orderly and controlled procedures involved in the development of a hook and an artificial foot were shown.

Dr. Glattly also displayed an array of typical upper-extremity and lower-extremity prostheses of modern design suitable for use by child or adult amputees. The exhibit included a step-by-step description of the process of plastic lamination of sockets and arm shells for upper-extremity prostheses. Shown, in addition, were the harness patterns found most efficient for use with functional arm components. In the display of lower-extremity prostheses for patients with hip disarticulation was a prosthesis with a plastic shank, a single-axis knee unit with adjustable mechanical friction, a wooden thigh section reinforced with laminated plastic, a one-piece laminated socket waistband, and a stride-length control strap. The display also featured a new Syme prosthesis incorporating a foot with a solid ankle and cushioned heel, a laminated plastic shank with a tibia pad, and a removable posterior section to accommodate the typically bulbous malleoli. Two types of experimental hydraulic units for above-the-knee amputees were described and are now being tested.

Dr. Glattly highlighted the activities of the prosthetics education centers at New York University and at the University of California at Los Angeles. He described and showed photographs of the short-term prosthetics courses offered at these two institutions for members of the prosthetics clinic team—physicians, prosthetists, physical therapists, and other auxiliary personnel. He also presented some of the publications developed in the Artificial Limb Program. Interested persons are invited to communicate with the Prosthetics Research Board for inclusion on the distribution list of the Board's official organ, the free publication *Artificial Limbs*.

Juvenile Amputees. Dr. J. Leonard Goldner [28] and Dr. Bert R. Titus [29].

The Transfixion Hip Prosthesis. Dr. Robert K. Lippmann [30] exhibited the transfixion hip prosthesis in a presentation designed to implement the original presentation of the transfixion prosthesis in The Journal, **39-A,** 759–785, July 1957. Its purpose was to familiarize orthpaedic surgeons with the device itself, its assembly, its insertion technique, its objectives, and its success in attaining them. Evidence of the fulfill-

26. 2222 Monument Avenue, Richmond 20, Virginia.
27. Prosthetics Research Board, National Academy of Sciences, Washington, D. C.
28. Orthopaedic Division, Duke Hospital, Durham, North Carolina.
29. Duke University Medical Center, Durham, North Carolina.
30. 910 Park Avenue, New York 21, N. Y.

ment of these objectives was presented in preoperative, postoperative, and follow-up roentgenograms of patients with the prosthesis in place for from two to seven years.

The function of the parts of the prosthesis was explained by charts, diagrams, and models of the prosthesis itself—removable from prepared specimens. The relatively small cross section of the device, and its integral strength, depending on bracing rather than bulk, contribute to its ease of insertion and its adaptability. Dr. Lippmann demonstrated the simple insertion technique and showed diagrams and color photographs of the actual procedure. He stressed that few accessory instruments were needed—the jig and drill being the only special instruments not encountered in the usual bone armamentarium. Dr. Lippmann emphasized that the transfixion prosthesis did not require femoral reaming.

The particular objective of the transfixion prosthesis, its firm and lasting fixation to the femur due to transfixion and utilization of the femoral-neck stump for support, was stressed. The strong resistance of the instrument to rotatory laxity yielded by the transfixion principle was demonstrated in models and prepared specimens. The supportive strength of the femoral neck at the critical trochanteric angle was similarly demonstrated. With the help of postoperative and follow-up roentgenograms in early cases, it was possible to show that the femoral neck is not the unreliable structure it was previously supposed to be when it is subjected to firm non-abrasive, non-shearing weight-bearing as provided by the prosthesis.

In support of the roentgenographic demonstration, a stress diagram was employed to show how the instrument applied a large share of firm weight-bearing to the stump of the femoral neck in physiological alignment; the remainder was dispersed broadly throughout the intramedullary arms of the instrument.

Gaining its integral strength from bracing rather than bulk, it was shown in models and diagrams how a prosthesis of relatively small diameter is applicable to large as well as small femora and to variable lengths of residual neck stumps. Both charts and specimens illustrated how this adaptability may be employed to approximate normal femoral-neck length or to adapt to hips with only a short femoral neck available.

Congenital Dislocation of the Hip, Conservative Aspects. Dr. Joseph E. Milgram [31].

Circulatory-System Changes Associated with Orthopaedic Conditions by Decades. Dr. Donald S. Miller [32] and Dr. Rowlin L. Lichter [33] designed their exhibit to instruct the young orthopaedic surgeon. They pointed out that it is imperative to be alert to the vascular complications of orthopaedic disorders according to the age groups in which they are likely to occur. The circulatory disturbance may have to receive priority in treatment over the orthopaedic derangement.

1. The exhibitors called attention to the fact that the vascular system of the premature newborn and full-term infant is extremely fragile; vasoconstriction and vasodilatation show poor intrinsic vasomotion. Infection, cachexia, Caffey's syndrome, congenital bands, exanthema, and congenital defects all affect the circulatory system adversely. The mechanisms of iatrogenic trauma to arteries when venipuncture is necessary are outlined. Sites for venipuncture were advised and precautionary measures listed. A full-size wax model of a cachectic baby, mounted in a recessed and illuminated plexiglass panel, was used as a demonstration.

2. In the age group from one to ten years, supracondylar fracture was said to present the most common orthopaedic problem with circulatory complications. The brachial artery may be compressed, irritated, or lacerated by sharp ends of bone. Bryant's traction for fractures of the femur may produce ischaemic contracture, or position may result in compression of vessels through tight bandaging and poor circulation. The exhibitors recommended corrective measures and advised precautions.

3. It was noted that the circulatory system is the most stable between age twenty and forty. Accidents, however, may destroy large blood vessels; aneurysms (true or false), arteriovenous fistulae, vasospasm from fractures, and thrombosis from displaced bones and dislocated joints are examples of possible results. Surgical replacement of blood vessels has improved the outlook.

4. Between the ages of forty and fifty years, post-traumatic dystrophy (Sudeck's bone atrophy) is observed more frequently by the orthopaedic surgeon than by the internist; the shoulder-hand syndrome, conversely, is observed often more by the internist. The symptoms are similar. The exhibitors noted the symptoms and treatment. A full-size wax model, mounted on an illuminated panel, illustrated the condition.

5. From sixty years of age upward, generalized arteriosclerosis influences the outcome of these conditions. They noted that the flow of blood through sclerotic vessels is reduced; peripheral inflow is poor; large vessels are fragile; and vasomotion deteriorates. The exhibitors called for care in diagnosis and caution against excessive or needless surgery which may lead to thrombosis of larger arteries, thrombophlebitis, vasothrombophlebitis, and ultimate gangrene. Two wax models were used to demonstrate the gangrenous result in an arteriosclerotic limb following hip-joint surgery.

The exhibitors used full-size drawings of medicosurgical features mounted on separate illuminated panels. The entire translucent center plexiglass panel showed the life-size figure of a man, and the associated circulatory-orthopaedic features were delineated in color and appropriately labeled.

31. Hospital for Joint Diseases, New York, N. Y.
32. 6 North Michigan Avenue, Chicago 2, Illinois.
33. Room 348, Young Hotel Building, Honolulu 13, Hawaii.

The Forequarter Amputation. Dr. H. F. Moseley [34] and Miss Helen T. MacArthur [35] presented an exhibit composed of three panels.

On the first panel, a table showed the main indications for the forequarter-amputation procedure which is usually performed following trauma or in an effort to remove a neoplasm. The following black and white illustrations were shown: (1) a print from the original engraving representing Samuel Wood who suffered a traumatic avulsion of the forequarter in 1737; (2) a reproduction of the frontispiece of Syme's monograph depicting the appearance and function of the upper limb after total scapulectomy; and (3) the arterial pattern in relation to the forequarter amputation. Several original color plates were grouped together. There were three plates showing the anatomy of the shoulder girdle from the anterior, superior, and posterior aspects, and one plate showing the lymphatic system in relation to the forequarter amputation. On the second panel, four plates showed, in detail, the steps of the classic Berger operation as performed from the anterior aspect and two plates showed the Littlewood technique of executing the operation from the posterior aspect. The third panel of the exhibit showed a series of black-and-white illustrations depicting scapulectomy and the various incisions for this procedure, three photographs of anatomical dissections of the area with explanatory diagrams, and two photographs of illustrative cases. A table of conclusions regarding the places of total and partial ablation of the shoulder girdle with or without the upper limb was included.

The following original material was also exhibited: (1) a commemorative medallion of Berger, (2) Berger's original monograph of 1887, (3) a copy of the original account of Dixi Crosby's first case of forequarter amputation for neoplasm, and (4) the exhibitors' monograph.

Osteotomy of the Ilium with Rotation of the Acetabular Roof for Congenital Dislocation of the Hip. Dr. Paul A. Pemberton [36].

Enteric Cytopathogenic Human Orphan and Coxsackie Viruses. Dr. Thomas M. Rivers [37], in his exhibit, explained the differences and similarities of Coxsackie and enteric cytopathogenic human orphan viruses which are prevalent throughout the world. Infections caused by these viruses are often confused with poliomyelitis. Coxsackie viruses are pathogenic for newborn mice, are recovered from stools and pharyngeal secretions from persons with or without illness, and are prevalent during the summer months as are poliomyelitis viruses. They are not pathogenic for adult mice nor are they neutralized by three types of poliomyelitis antisera. There are twenty-four known types of Coxsackie and enteric cytopathogenic human orphan viruses recognized at the present time. Coxsackie viruses have been shown to cause the following clinical syndromes: herpangina, pleurodynia, aseptic meningitis, paralysis (in rare instances), and neonatal encephalohepatic myocarditis.

Dr. Rivers indicated that Coxsackie-virus infections may masquerade as poliomyelitis. In 1952, several patients studied during the Gamma Globulin Field Trials who were diagnosed as having paralytic poliomyelitis were found to be infected with Coxsackie B-5 virus. In 1956, Russian Type 4 poliomyelitis virus was identified as Coxsackie A-7 virus. In 1957, an epidemic of non-paralytic poliomyelitis in Durham, North Carolina, was actually due to Coxsackie B-5 virus.

The enteric cytopathogenic human orphan viruses are cytopathogenic for certain human and monkey cells in tissue culture, are neutralized by pooled human gamma globulin, are prevalent during the summer months as are poliomyelitis viruses, and are recovered from stools and pharyngeal secretions of persons with or without illness. They are not pathogenic for monkeys, are not neutralized by three types of poliomyelitis antisera, are not neutralized by antisera for Coxsackie viruses, and, with two possible exceptions, are not pathogenic for infant mice. Enteric cytopathogenic human orphan viruses have been shown to cause the following clinical syndromes: aseptic meningitis, steatorrhoeic enteritis, and paralysis. Dr. Rivers indicated that types of enteric cytopathogenic human orphan viruses may masquerade as poliomyelitis. In 1954 and 1955, enteric cytopathogenic human orphan virus Type 6 was found to be the agent responsible for epidemics of aseptic meningitis in Buffalo, New York, Washington, D. C., and Stockholm, Sweden. In Boston, in 1954, a type of enteric cytopathogenic human orphan virus was isolated from twenty-two patients with paralytic poliomyelitis. In Wisconsin, in 1957, enteric cytopathogenic human orphan virus Type 9 was responsible for an epidemic of aseptic meningitis with rash, erroneously diagnosed as non-paralytic poliomyelitis.

Occupational Therapy—A Rehabilitation Service. Dr. Dean W. Roberts [38], Miss Jayne Shover [39], Miss Elizabeth Wagner [40], and Miss Florence Stattel [41] of the National Society for Crippled Children and Adults, Inc., presented an exhibit which showed the occupational therapist as an integral

34. Royal Victoria Hospital, Montreal 2, Quebec, Canada.
35. Royal Victoria Hospital, Montreal 2, Quebec, Canada.
36. 220 Boston Building, Salt Lake City, Utah.
37. National Foundation for Infantile Paralysis, New York 17, N. Y.
38. National Society for Crippled Children and Adults, Inc., Chicago, Illinois.
39. National Society for Crippled Children and Adults, Inc., Chicago, Illinois.
40. National Society for Crippled Children and Adults, Inc., Chicago, Illinois.
41. National Society for Crippled Children and Adults, Inc., Chicago, Illinois.

member of the rehabilitation team, contributing to the mental, physical, and psychological care and treatment of the patient and that vocational objectives run parallel with the physical restoration.

The exhibit illustrated the occupational-therapy prescription coming from the doctor to the occupational therapist, and outlined the four main areas of occupational therapy for patients who by birth, illness, or injury are deprived of normal function of the neuromuscular and associated skeletal system. The following points in rehabilitation were discussed:

1. *Specific treatment:* Exercises of localized portions of the body (for instance, abduction, flexion, and elevation of the shoulder) through the use of specific activities to promote strength, range of motion, and coordination are employed. Patients are generally referred when active motion is present or possible. The tools of the occupational therapist are the therapeutic use of manual skills, crafts, and recreation.

2. *Self-care:* Training in proficiency in the activities of daily living, for example, personal care, dressing, feeding, and writing. Adapted devices which enable a person to reach his level of independence are constructed.

3. *Pre-vocational exploration:* An appraisal is made of a disabled patient's personality, performance, and physical capacities in relation to his being considered for productive employment. The occupational therapist works closely with the vocational counselor after medical approval has been given. The vocational counselor requests the occupational therapist to give selective-skills tests in designated areas.

4. *Avocational pursuits:* When the nature and severity of the disability, whether permanent or progressive, indicates that gainful employment is not likely, the resources of the individual are explored to find activities that are satisfying within the capabilities of the patient. The benefits derived are maintenance of physical function and improved social standing in his family.

Within the framework of the Society's services, the clinical types of patients for whom occupational therapy may be prescribed are: orthopaedic, neurological, paediatric, psychiatric, tuberculous, and geriatric. Occupational therapy units sponsored by affiliates of the Society may be found in hospitals, treatment centers, rehabilitation centers, schools, camps, and the home. Complimentary literature on occupational therapy published by the Society and by the American Occupational Therapy Association was available. A registered occupational therapist was present to answer questions on occupational therapy and other related services.

The National Society for Cripple Children and Adults, Inc. is a national federation of nearly 1700 state and local member societies. It provides needed services in the fields of health, welfare, education, recreation, employment, and rehabilitation. Its three-point program includes education, research, and direct services.

Synovia, Its Normal and Pathological Variations. Dr. Howard B. Shorbe [42], Dr. J. N. Owens, Jr. [43], and Dr. William N. Harsha [44].

Hypercortisonism in Patients with Rheumatoid Arthritis. Dr. C. H. Slocumb [45], Dr. H. F. Polley [46], Dr. L. E. Ward [47], and Dr. J. G. Mayne [48].

The Embryology of the Hip Joint. Dr. William S. Smith [49], Dr. R. F. Slager [50], and Dr. C. R. Coleman [51] presented the development of the human hip joint from the six-millimeter embryo to birth. Photomicrographs accompanied by photographs of the foetus at a corresponding age depicted the various stages of development ranging up to the 120-millimeter stage. The differentiation of the limb bud from mesenchyma to femur, pelvis, hip joint, capsule, vessels, and ligamentum teres was noted. The rotation of the limb bud was also demonstrated.

The soft tissue was removed from foetuses ranging in development from 120 millimeters to fifty centimeters and roentgenograms were made of the specimens including the articulated, disarticulated, and sagittally sectioned pelvis. Clearing away the soft tissue prior to roentgenographic examination was shown to provide three distinct advantages over previous studies on late fetal development: (1) sharp outline between the relative amounts of bone and cartilage in the development of the hip joint, (2) ease of understanding of the time sequence of the various ossification centers, (3) the pronounced differences between the appearance of the articulated and disarticulated pelvis, and (4) a clearer understanding of the true nature of the so-called acetabular index.

A graph also included the relative amounts of mesenchyma, cartilage, and bone in the developing hip during the normal intra-uterine period.

42. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.
43. 605 N.W. 10th Street, Oklahoma City 3, Oklahoma.
44. 1429 N.W. 36th Street, Oklahoma City 3, Oklahoma.
45. 102 Second Avenue, S.W., Rochester, Minnesota.
46. 200 First Street, S.W., Rochester, Minnesota.
47. Mayo Clinic, Rochester, Minnesota.
48. 102 Second Avenue, S.W., Rochester, Minnesota.
49. University Hospital, Columbus, Ohio.
50. 897 Thomas Road, Columbus, Ohio.
51. 1815 Kings Court, Columbus, Ohio.

The Role of Antibiotic-Resistant Staphylococci in Hospital Infections. Dr. Howard H. Steel [52], Dr. Elsie R. Carrington [53], Dr. H. Taylor Caswell [54], Dr. Norman Learner [55], Dr. Kenneth Schreck [56], and Dr. Robert Tyson [57] presented an exhibit which gave their experience with *Staphylococcus aureus* infections in a large general hospital. The display outlined the epidemiological approach and suggested methods by which the problem might be controlled.

Benign Destructive Lesions of Bone. Dr. Marcus J. Stewart [58] and Dr. W. Scott Gilmer, Jr.[59].

The Extra-Osseous and Intra-Osseous Blood Supply of the Talus. Dr. C. R. Sullivan [60], Dr. P. J. Kelly [61], Dr. R. A. Haliburton [62], and Dr. A. H. Bulbulian [63].

Growth in Transplanted Bone. Dr. Charles F. Thompson [64], Dr. Frank B. Throop [65], and Dr. Edward V. Schaffer [66] presented a display showing that normal growth function in autogenous-bone transplants which include the entire growth unit survives in variable degree. Roentgenograms, gross specimens, and photomicrographs illustrated 120 autogenous-bone transplants in sixty-eight dogs (average age 1.7 months). Forty-two survivors were observed until skeletal maturity. In 40 per cent the results were good, with normal growth in length and duration; in 30 per cent the results were poor; in 30 per cent the results were failures. The factors contributing to good results were:

1. *Age:* Maximum results in five-week-old dogs decreased in the animals that were six, eight, and twelve weeks old.

2. *Surgical technique:* Trauma to the epiphysis or periosteum, fragmentation at the osteotomy site, or deficient apposition and fixation of the transplant to the host bone contributed to incomplete growth.

3. *Immediate functional stress:* Postoperatively dogs were permitted full outdoor activity with no external fixation.

4. *Intramedullary fixation of the transplant to the host bone:* This is the only technique to which success is attributable in recent transplantations. Previous experimenters used bone sutures or soft-tissue support for fixation of end-to-end transplants.

In homogenous-bone transplants in dogs there was uniform failure in (1) fetal transplants at or near full term; (2) fetal transplants from newborn dogs; (3) transplants from litter mates; and (4) transplants from five-week-old dogs to eight-week-old dogs.

Roentgenograms, growth charts, and clinical photographs illustrated an autogenous-bone transplantation in a male infant with congenital absence of the proximal fibular epiphysis. Preoperatively the fibula had been advanced at the ankle by means of skeletal traction. When the child was six months old, the entire third metatarsal bone was transplanted from the foot to the ipsilateral fibula. When the child was two years and eight months old, the ossification center appeared in the epiphysis of the transplant, two to three months before those in the donor foot. The growth of the transplant was equal to that of the metatarsals when the child was five years and six months old.

52. 3401 North Broad Street, Philadelphia 40, Pennsylvania.
53. 3401 North Broad Street, Philadelphia 40, Pennsylvania.
54. 3401 North Broad Street, Philadelphia 40, Pennsylvania.
55. 255 South 17th Street, Philadelphia, Pennsylvania.
56. Temple University School of Medicine, Philadelphia, Pennsylvania.
57. Temple University Medical Center, Philadelphia, Pennsylvania.
58. 869 Madison Avenue, Memphis, Tennessee.
59. 869 Madison Avenue, Memphis, Tennessee.
60. Mayo Clinic, Rochester, Minnesota.
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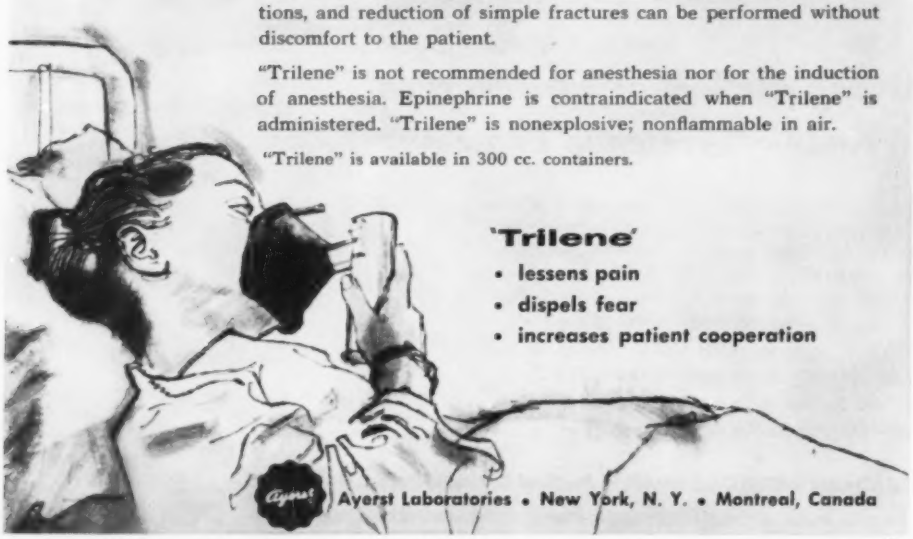

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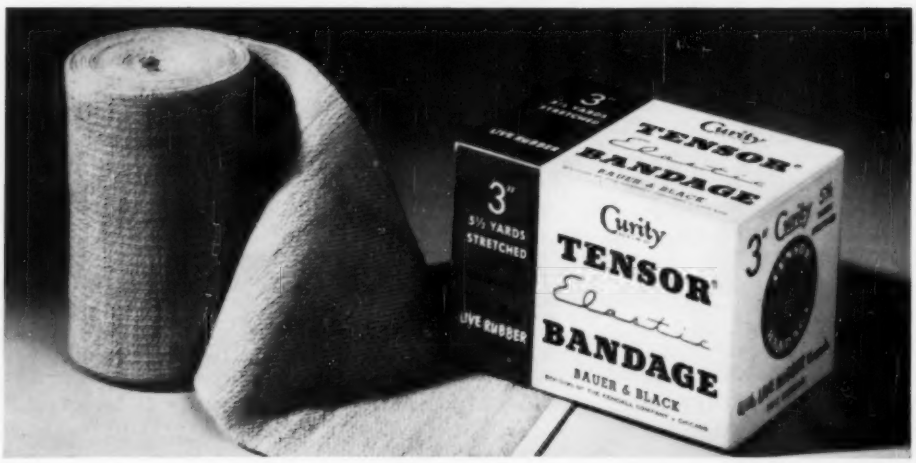

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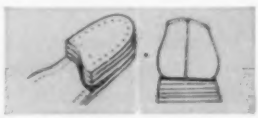

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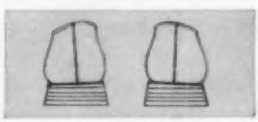

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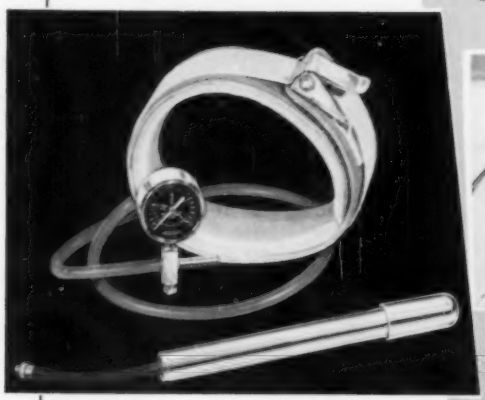

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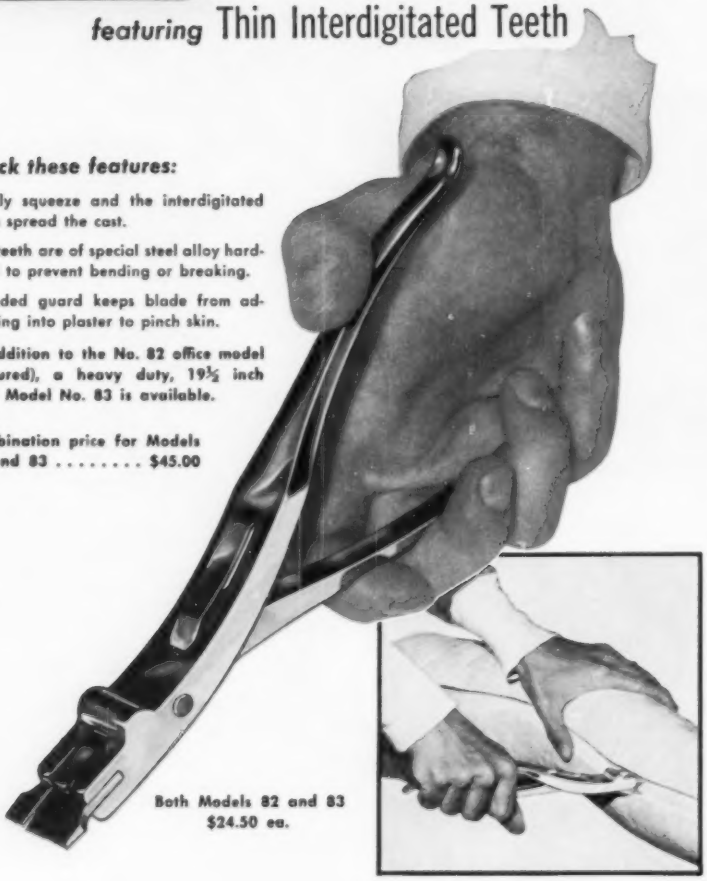

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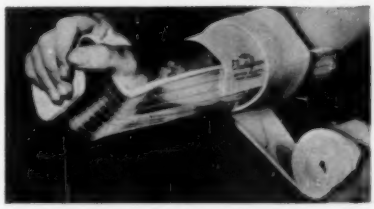

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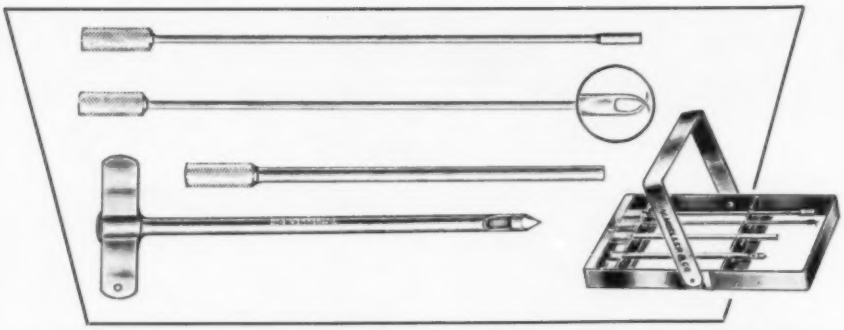

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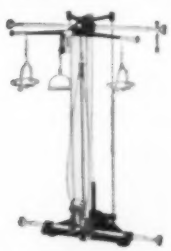

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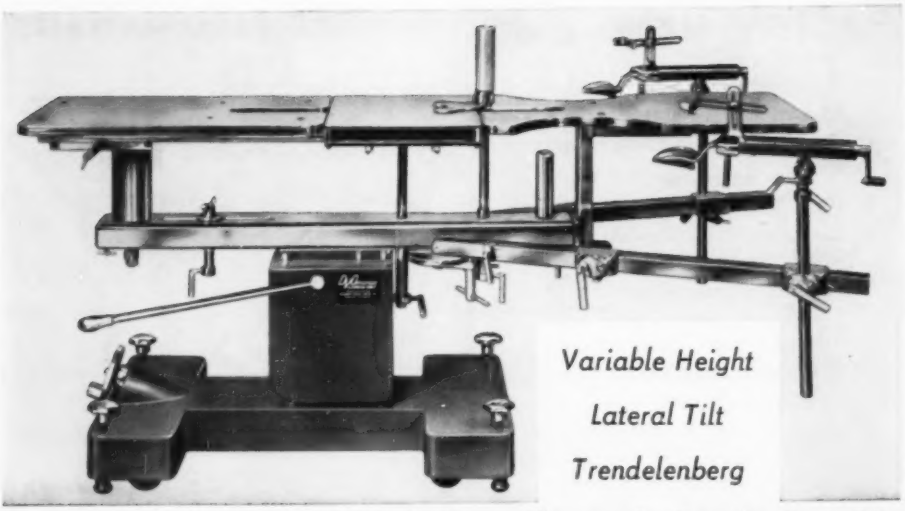

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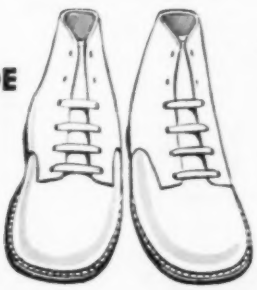

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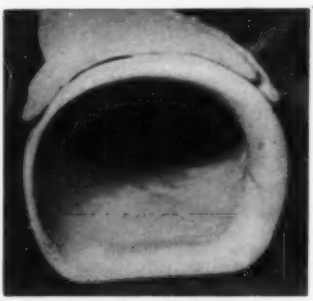

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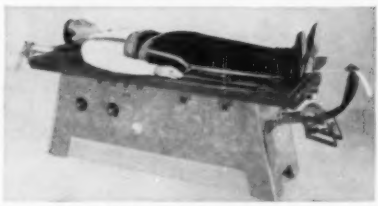

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List of Advertisers

JUNE 1958

	PAGE
Aireloom Bedding Company	56
C. H. Alden Shoe Company	6
American Cyanamid Company, Surgical Products Division	25
American Sterilizer Company	15
Austenal, Inc.	39, 40, 41, 42
Ayerst Laboratories	48
Bauer & Black, Division of the Kendall Company	46, 49
The Berivon Company	4, 5
Bowen & Company, Inc.	13
Braverman Shoes	62
Bristol Laboratories, Inc.	33, 34
S. H. Camp and Company	12
Chattanooga Pharmacal Company	54
G. W. Chesbrough, Inc.	55
Chesebrough-Pond's, Inc., Professional Products Division	10
Gilbert Hyde Chick Company	61
Codman & Shurtleff, Inc.	11
Connecticut Bandage Mills, Inc.	53
DePuy Manufacturing Company, Inc.	7
Eastman Kodak Company	47
Elgin Exercise Appliance Co.	55
Fillauer Surgical Supplies, Inc.	57
Florida Brace Corporation	58
Freeman Manufacturing Company	53
S. R. Gittens	60
Hack Shoe Company	61
J. E. Hanger, Inc.	20
Herbst Shoe Manufacturing Company	18
Hill Laboratories Company	63
House of Bidwell	63
Ken Standard Corp.	60
Kleistone Rubber Company	62
McNeil Laboratories, Inc.	8, 9
M. J. Markell Shoe Company, Inc.	21
Market Forge Company	23
Medical Research Specialties	22
Merck Sharpe & Dohme, Division of Merck & Co., Inc.	28, 29
Miller Brace Co.	63
Minnesota Orthopedic Services	60
V. Mueller & Co.	54
Northwestern University	59
Orthopedic Equipment Co.	24
Orthopedic Frame Company	38, 52
J. A. Preston Corp.	58
Price Filler Machine & Mfg. Co.	57
Richards Manufacturing Company	26, 51
Roberts, Johnson & Rand, Division of International Shoe Company	50
Schering Corporation	17
Chas. A. Schmidt Surgical Instrument Company	27
Sealy Mattress Company	59
Simmons Company	43, 44
Smith Kline & French Laboratories	14
Spencer, Incorporated	35
E. R. Squibb & Sons	31
Truform Anatomical Supports	16
The United Limb and Brace Co., Inc.	61
United States Manufacturing Company	32
Wallace Laboratories	19
H. Weniger	62, 63
Westwood Orthopaedic & Surgical Appliance Company	62
Wilmot Castle Company	56
Wright Manufacturing Company	30
The Year Book Publishers, Inc.	45
Zimmer Manufacturing Company	36, 37

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